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OF THE

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American Welding Society

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JOURNAL

OF THE

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AMERICAN WELDING SOCIETY
ESTABLISHED 1919
JOURNAL

Volume 5 JANUARY, 1926 Number 1

GROWTH OF THE WELDING INDUSTRY

The shortness of the period of the development of the welding industry has not enabled it to gather the careful statistics and charts which are now available in other industries as to growth, money value and relative standing.

While, unfortunately, no direct figures are available for measuring the total volume of welding in 1925 as compared with previous years, nevertheless information has been supplied by a few large corporations who have been using welding in their work or who have been selling aparatus and materials for use by the welding industry. From information supplied by these, it is conservative to state that more than two and one-half times as much welding is being done now as compared with that in 1921.

ANNUAL MEETING

The annual meeting of the American Welding Society will be held in New York on April 21, 22 and 23. The Meetings and Papers Committee are making careful plans to make this occasion an outstanding one in the history of the American Welding Society. Some very valuable papers for the technical session are being secured which will be of wide interest to the welding industry. A number of novel features are being arranged. A complete program will be given in the next issue of the Journal.

RESEARCH

A report of the fatigue and other tests made by the A. O. Smith Corporation to demonstrate the suitability of welding for Penstock lines given elsewhere in this issue is a remarkable demonstration of the need of careful scientific tests in the welding field.

This report merits the careful study of every member of the Society and shows the need of the investigational program proposed by the American Bureau of Welding in the pressure vessel field.

Welding possesses certain fundamental inherent, economical advantages for joining metals that will eventually force its universal adoption. Research can speed up this period by furnishing accurate information as to the quality and physical properties of welded joints and how they can be improved. Accurate information is needed by the designer, engineer and draftsman in order that the most economical and best joint may be produced and one that will withstand the stresses that it will meet in service. In particular, information must be secured as to the endurance limit of welded joints subjected to a great number of variations in cycles of stress. Today it is universally recognized that research is a paying proposition in any industry regardless of whether new or of long standing. Research has been able to cut down the cycle of development from the discovery of scientific facts to inventions, applications and mass production from a long span of years to a few months in special industries. In welding it has been and probably will be the greatest factor of progress for some time.

BOUND VOLUMES

A limited number of bound volumes of the JOURNAL OF THE AMERICAN WELDING SOCIETY for the year 1925 are now available for distribution. These volumes contain subject and authors indexes and form a permanent record of the publications of the Society during the past year. These volumes are available to members of the Society at $5.00 per copy and to non-members at $10 per copy.

A few volumes are still left for the years 1922, 1923 and 1924.

HONOR LIST

Membership Activities

September, October and November

Sponsor	Classes
G. W. Swan	2 Class B, 1 Class C, 3 Class D
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Hugh Griffiths, Foreman Welder, Truck Equipment Company, (res.) 797 Main Street, Buffalo, N. Y.

Andy Rices, Acetylene Welder, Allan Mfg. & Welding Company, Inc., (res.) 253 Stanton Street, Buffalo, N. Y.

Walter Titus, Welder, Penn. R. R., (res.) 259 Babcock Street, Buffalo, N. Y.

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George C. Thompson, Electric Welder, (res.) San Juancito, Honduras, Central America.

George E. Tibbits, General Supt., S. F. Bowser & Company, Fort Wayne, Ind.

SECTION ACTIVITIES

Detroit

The December meeting, held on the 11th, was a joint meeting with the Detroit Engineering Society. There was an attendance of 125. Prof. C. A. Adams, director of the American Bureau of Welding, explained the aims and activities of the society. Great interest and enthusiasm was displayed in the possibilities of this section.

Los Angeles

The December meeting of the section was held on the 17th, at which was shown a four-reel picture on "Manufacture of Wire," which was accompanied by an explanatory talk by Mr. C. A. Vicklund. The next meeting will be held on Jan. 21, at which Mr. A. G. Bissell of the Westinghouse Electric and Manufacturing Co. will present a paper on "Structural Steel Welding."

San Francisco

The regular monthly meeting was held on Dec. 18, at the Engineers' Club, at which Mr. C. R. Price of the Associated Oil Company discussed the design and erection of several welded steel buildings recently constructed at their refinery at Caron, Cal. This paper was illustrated by lantern slides. On Jan. 15, Mr. A. G. Bissell, Westinghouse Electric and Manufacturing Co., will deliver a paper on "Adaptability of Electric Arc Welding to the Fabrication of Steel Structures."

Pittsburgh

The December meeting was held on the 11th, at which Mr. G. O. Carter of the Linde Air Products Company presented a paper, "Design for Oxy-Acetylene Welding." There were 48 in attendance, among which were students from the Carnegie Technical School. The January meeting will be held on the 15th, at which Mr. Robert E. Kinkead of the Lincoln Electric Co. will present a paper on "Some Interesting Characteristics of the Electric Arc."

Chicago

The December meeting of the section was held on the 4th, in the rooms of the Western Society of Engineers. The speaker of the evening was Mr. J. W. Haygood, service supervisor, Western Division of the Linde Air Products Company, who delivered a paper on "Procedure Control for Oxwelding Cast Iron Heater Sections." There was considerable discussion of this very interesting subject. Lantern slides were also shown. The January meeting was held on the 8th, at which Mr. A. M. Candy, Westinghouse Electric & Manufacturing Co., presented a paper on "Cutting Railroad Cars with the Electric Arc." This address included a very complete set of lantern slides, based upon the activities of the Pennsylvania Railroad in cutting up cars with the electric arc. Mr. Jonathan Wolfe of the Chicago Surface Lines presented a short address, entitled "Chicago's Surface Transportation," together with moving pictures, which were of interest to every member present.

Cleveland

The January meeting of this section will be held on the 19th, at the Cleveland Engineering Society rooms, Hotel Winton. A Get Acquainted Dinner will be served at 6.30, after which the meeting will be held. Mr. H. E. Winkelman will present paper on "Arc-Welding Cast Iron." The electric arc-welding of cast iron, including cylinder blocks, will be left open for joint debate by those attending.

New York

A joint meeting of the New York Section and the local section of the A. S. M. E. was held in the Engineering Societies Building on Jan. 14. About 400 people were in attendance. The following papers were presented: "A Partial Review of Outstanding

Applications of Welding," E. H. Ewertz; "Welded Pressure Vessels," S. W. Miller; "Welding as a Means of Fabricating Tanks, Vessels and Pipes," William Schenstrom.

Some very interesting discussions developed as a result of these papers, which emphasized the fact that welding is now being applied to a large variety of applications involving millions of dollars, and that the mechanical engineer must come to the realization that a knowledge of welding should constitute a part of his training. Each paper was illustrated by lantern slides.

The next meeting of the New York Section will be held on Feb. 16, in the Edison Lamp Works, General Electric Company, at Harrison, N. J. Members and their guests will be afforded an opportunity to see a really remarkable demonstration of the development of modern lighting. It is also planned to have a short paper of interest to the welding people.

EMPLOYMENT SERVICE BULLETIN

Opportunities.—The Society is glad to learn of desirable opportunities from responsible sources, announcements of which will be published without charge in the BULLETIN.

Services Available.—Under this heading brief announcements (not more than seventy-five words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period, names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Society's Office not later than the thirtieth of the month if publication in the following issue is desired. *ALL REPLIES should be Addressed to the number Indicated in Each Case and Mailed to Society Headquarters.*

POSITIONS VACANT

V-31. Salesmen and Estimator wanted. Required by one of the largest and best established job welding concerns in New York. Preferably a man who has experience or one who has a fair knowledge of welding, both gas and arc, and who is accustomed to doing business with large service stations and fleet owners.

An interesting proposition will be made to the right man, which assures a good income on a salary and commission basis, to a live wire who can produce. All details will be treated in confidence.

Services Available

A-39. Acetylene welder desires position. Have had six years' experience in welding and brazing of all metals. Have been connected with the Todd Engineering Co., The Westchester and Lighting Co., and the National Transit Pump and Machine Co. Can give references.

A-40. Welder desires position. Am an expert in oxy-acetylene welding and cutting and can also do thermit welding. Have had seven years' experience in railroad repair shops, one year as pipe line welder, one year as general cast iron welder, one year as general sawmill welder, one year as repair man and brazing of all methods. Understand preheating. Prefer a job in some northern State around Chicago. Can run a shop as welder foreman in either railroad or contract shop. Can inspect welders. Capable of being service demonstrator and salesman.

Penstock Demonstration Test
October 11, 12 and 13, 1925

C. C. JOYS, JR.†

When it became known that this company contemplated entering the Penstock manufacturing field great interest was manifested by hydroelectric engineers from a research standpoint.

This interest was centered in the action of waterhammer in Penstock lines and the results of this action on the metal in the lines.

We were advised that it had been impossible to get anyone to devise mechanical apparatus for reproducing waterhammer action, let alone build it, and run tests as research for this very important industry, that might uncover results that would enable them to more accurately design Penstocks in the future.

With this in view our engineers designed the apparatus described in the following pages. This design was then submitted to some of the leading hydroelectric engineers and their approval of the same received.

It must also be stated here that these same engineers set the design of the vessel to be tested.

Full description of the test by our engineers will be found in the body of this report, together with detailed diagrams of results.

In view of the wide interest created by the announcement of this test throughout the engineering fraternity, it was decided to invite the officers of the following organizations to attend:

American Society of Mechanical Engineers,
American Engineering Standards Committee,
American Institute of Electrical Engineers,
American Society for Testing Materials,
American Society of Civil Engineers,
American Institute of Mining & Metallurgical Engineers,
American Welding Society,
American Bureau of Welding,
Electrical Testing Laboratories.

The following were in attendance during at least a portion of the duration of the tests which were conducted at our plant Oct. 11, 12 and 13, 1925.

R. L. Duff, Metallurgist, Standard Oil Company of New Jersey, Elizabeth, N. J.

John W. Turner, Mechanical Engineer, General Boilers Company, Waukegan, Ill.

J. A. Hance, Engineer, Specifications and Tests, Baldwin Locomotive Works. Philadelphia, Pa.

F. W. Martin, Mechanical Engineer, Sargent & Lundy, Chicago, Ill.

W. Dreyer, Assistant Engineer, Division of Civil Engineering, Pacific Gas & Electric Company, San Francisco, Cal.

L. F. Harza, Construction Engineer, Chicago, Ill.

H. P. McKean, Designing Engineer, L. F. Harza, Chicago, Ill.

†Manager of Sales, Oil Field Products, A. O. Smith Corp.

C. W. Obert, Secretary, A. S. M. E., Boiler Code Committee, New York, N. Y.
W. C. Hackman, Hackman Manufacturing Co., Milwaukee, Wis.
M. A. Dantzler, Assistant Manager, Air Reduction Sales Company, Milwaukee, Wis.
C. F. Williams, Industrial Engineer, Air Reduction Sales Company, Milwaukee, Wis.
S. W. Miller, Union Carbide Laboratories, New York, N. Y.
J. P. Morrison, Chief Inspector, Hartford Steam Boiler Inspection and Insurance Co., Hartford, Conn.
Frank Schwab, President, Schwab-LeZotte Boiler Co., Milwaukee, Wis.
H. F. Bowie, Sr., Inspector, Hartford Steam Boiler & Inspection Co., Milwaukee, Wis.
M. A. Edgar, State Boiler Inspector, Industrial Commission, Madison, Wis.
F. Trenkamp, Jr., Sewerage Commission, Milwaukee, Wis.
H. Erskine Nicol, Sewerage Commission, Milwaukee, Wis.
W. M. DeBerard, Western Editor, *Engineering News Record*, Chicago, Ill.
Thomas Wilson, Western Editor, *Power*, Chicago, Ill.
William Schenstrom, Consulting Engineer, Brooklyn, N. Y.
J. B. Shipley, Pittsburgh Wood Preserving Co., Pittsburgh, Pa.
Oswald Spier, Engineer, Feather River Power Company, San Francisco, Cal.
E. R. Davis, Inspector, The Texas Company, Port Arthur, Tex.
Darwin W. Townsend, Assistant Chief Engineer, Sewerage Commission, Milwaukee, Wis.
W. J. Sando, Consulting Engineer, Milwaukee, Wis.
C. F. Werdermann, Jr., Boiler Inspector, Fidelity & Casualty Co. of New York, Milwaukee, Wis.
C. E. Bronson, Mechanical Engineer, Kewanee Boiler Company, Kewanee, Ill.
George Gordon, Assistant to General Manager of Sales, Lukens Steel Company, Coatesville, Pa.
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R. H. Weins, Engineer, Edw. E. Gillen Company, Milwaukee, Wis.
John Anderson, Vice-President, in charge of Power, T. M. E. R. & L. Co., Milwaukee, Wis.
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I. Harter, Babcock-Wilcox Company, New York, N. Y.
Dr. D. S. Jacobus, Babcock-Wilcox Company, New York, N. Y.
H. J. Kerr, Babcock-Wilcox Co., New York, N. Y.
H. Rensford, Chief Inspector, Maryland Casualty Co., Milwaukee, Wis.
Herman W. Falk, President, The Falk Company, Milwaukee, Wis.
W. C. Shaw, Pumping Engineer, Allis-Chalmers Mfg. Co., Milwaukee, Wis.
A. J. Brown, Electrical Department, Allis-Chalmers Mfg. Co., Milwaukee, Wis.
H. Jacobson, Works Manager, Logemann Brothers Company, Milwaukee, Wis.
Walter Plehn, Sales Engineer, Bucyrus Company, Milwaukee, Wis.
H. L. Doolittle, Assistant Construction Engineer, Southern California Edison Co., Los Angeles, Cal.
Arnold Pfau, Construction Engineer, Hydraulic Department, Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Arnold Pfau, Jr., Electrical Engineer, American Resistor Corporation, Milwaukee, Wis.
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S. H. Smith, Representative, Universal Oxygen Company, Milwaukee, Wis.
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Robert F. Vogt, Assistant Construction Engineer, Allis-Chalmers Mfg. Co., Milwaukee. Wis.
G. C. Wilson, Director of Steam and Gas Engineering Laboratory, University of Wisconsin, Madison, Wis.

W. Brady, Director Chicago Section, American Welding Society, Chicago, Ill.
H. J. Mueller, President, Universal Oxygen Company, Sheboygan, Wis.
O. T. Wilson, President, General Boilers Company, Waukegan, Ill.
C. S. Lincoln, Designing Engineer, Allis-Chalmers Mfg. Co., Milwaukee, Wis.
O. C. Voss, Superintendent Boiler Department, Allis-Chalmers Mfg. Co., Milwaukee, Wis.
F. T. McDonough, Representative, Niles-Bement Pond Company, Milwaukee, Wis.
E. V. Walker, Representative, National Fire Proofing Co., Milwaukee, Wis.

The summary of the results of this Penstock test are as follows:

Number of shocks	6440
Pressure	1000 lb. to 2000 lb.
Breaking Pressure	2700 lb. per sq. in.
Fibre Stress	32,600 lb. per sq. in.

A previous test conducted on April 28, 1925, on a similar vessel, but which had not been subjected to shocks such as were reproduced in this test, withstood a pressure of 4700 lb. (fiber stress of 56,400 lb. per sq. in.), when the center of the cast steel head gave way.

Therefore, it appeared as though something had taken place to materially reduce the strength of the metal in the Penstock during the test, that needed very careful study.

In fairness to those who witnessed this Penstock test on Oct. 11 to 13, and to further give to the engineers interested, an unbiased analysis as to the cause of the break, we engaged Prof. T. McLean Jasper of the University of Illinois, recognized to be one of the highest authorities on the fatigue of metals in this country, to make a report after a thorough study of the metal in the fractured penstock.

Professor Jasper's report is reproduced herewith.

From the report of Professor Jasper and the engineers of this company, it is evident that fatigue was the ultimate cause of the break.

INVESTIGATION OF THE FATIGUE OF METALS

UNIVERSITY OF ILLINOIS

Urbana November 23, 1925.

Mr. C. C. Joys, Jr.,
Manager of Sales,
Milwaukee, Wis.

Dear Mr. Joys:

Enclosed, please find report on the steel from the cylinder which you tested in repeated stress. I have expedited this report. The observations are those which the writer feels are essential in drawing the conclusion that the failure was one primarily of fatigue.

Under separate cover are being sent seven specimens:

(a) Typical fatigue fracture.
(b) Specimens of fatigue fractures from cylinder steel.
(c) Impact specimens from cylinder steel.
(d) Tensile specimens from cylinder steel.

No. 10 represents steel not subjected to hydro-static test. No. 20 represents steel subjected to hydro-static test.

Note in impact test specimen, the apparent larger grain in the No. 20 specimen and in the tensile specimen the pock-marked surface in the No. 20 steel.

Yours very truly,
T. M. JASPER,
Special Research Associate Professor of Engineering Materials.

TMJ:EW

Report on Cause of Failure in Metal of A. O. Smith Cylinder Tested in Repeated Stress Under Repeated Hydrostatic Loading

T. JASPER, Univ. of Illinois

The test was carried out by the engineers of the A. O. Smith Corporation and consisted of a circular cylinder with four longitudinally welded joints and certain welded joints at right angles to these. The cylinder was subjected to about 7000 repetitions of hydrostatic load and one slowly applied load to failure. The fracture was a longitudinal one away from the welded joints.

The calculated maximum impressed stress in the material of the cylinder during the repetitions of hydrostatic pressure was 22,500 lb. per sq. in. The calculated maximum impressed stress during the loading of the cylinder to failure was 32,600 lb. per sq. in. The cause of the failure of the test cylinder at such a low impressed stress is one which the following tests were designed to decide.

From the standpoint of the impressed stress on the cylinder at failure, it would seem that the cause of this failure was a general fatigue breakdown because of the impressed stress value as compared with the ultimate strength value of the material of which the cylinder was made. From a study of the fracture itself, the answer is not so clear because in general fatigue fractures are quite different from the one shown in this case. This case does not represent fatigue to destruction because the bursting load was a static one, and for this reason it was recognized that the fracture, although not one that showed the typical fatigue fracture, might still be the result primarily of fatigue and finally that of static failure in the metal which had been so weakened by the progress of the intercrystalline fatigue that it failed at a relatively low ultimate strength.

The design of the following experiments was made, therefore, with the idea in mind that if fatigue was responsible for the failure of the cylinder, this could be indicated by testing the metal that had been subjected to hydrostatic test condition and comparing it with metal of the same plate, but which had not been subjected to such test conditions.

It was recognized that the metal subjected to the hydrostatic test would fail at the weakest spot in the metal or at point of maximum stress, and that the adjacent metal at any particular spot under either one of these conditions would give lower static elastic and fatigue results than the metal from a plate that had been unstressed.

The experiments as carried out were made on two sets of specimens, one set made entirely from a plate which failed under the original hydrostatic test and one set from a part of the same plate

but which was not previously tested. The test results are as follows:

Static Elastic or Fatigue Property	Metal from the Untested Plate Values	Average	Metal from the Tested Plate Values	Average	Percent Change in Property of the Metal Due to Hydrostatic Test
Brinell hardness No..	112.2		106.2		
	113.6	112.0	106.8	106.7	— 4.7
	110.2		106.8		
			106.8		
Impact bending, energy of rupture, ft. lb.	26.7		22.2		
	27.8	27.0	18.1	21.5	— 20.4
	26.4		22.1		
			23.5		
Elastic limit, lb. per sq. in.	35,000		27,500		
	35,000	34,800	29,000	28,500	— 18.1
	34,500		29,000		
Yield point, lb. per sq. in.	37,000		28,800		
	36,300	37,000	30,900	30,200	— 22.5
	37,800		30,900		
Ultimate strength, lb. per sq. in.	65,300		62,500		
	64,000	65,900	62,100	62,200	— 5.9
	67,500		62,500		
Reduction of area, per cent	50.0		52.1		
	54.4	54.1	55.3	53.3	— 0.4
	54.8		52.4		
Elongation in 2 in., per cent	30.5		26.0		
	28.0	29.8	31.0	28.2	— 5.4
	30.0		27.5		
Modulus of elasticity, lb. per sq. in.	30,500,000		28,400,000		— 6.9
Endurance limit, rotating beam, lb. per sq. in.	31,000		28,000		— 9.7

The tests offer a study of conditions such as has not heretofore been available to the writer and as a matter of fact to no one working on fatigue so far as he knows. It is, therefore, of considerable academic interest to have this series of experiments made, because it throws some light on fatigue breakdown. The metal in the hydrostatic test evidently had been subjected throughout its whole mass to the effect of over-fatiguing. It is of considerable academic interest to find out the effect of over-fatiguing on the static and elastic properties and also the metallographic state of the metal.

The writer is satisfied that the metal taken from the hydrostatic test specimen had been subjected to fatigue above its endurance limit and, although the impressed stress during the test was below the endurance limit, results shown by the rotating beam machine, nevertheless he is willing to hold firmly to this conviction. The reasons are as follows:

In the first place the metal was subjected to repeated direct stress which, in the Investigation of the Fatigue of Metals carried

out at the University of Illinois, it has been found that the endurance limit under such conditions is approximately two-thirds of the rotating beam endurance limit due to the more violent method of application of stress and also probably due to the fact that the whole of the metal of the cross section is subjected to high stresses at the same time. In the second place the cylinder was subjected to initial stresses due to welding, and for four specimens tested by cutting the cylinders in two and measuring the strain relief and interpreting the strains in terms of stresses, an average stress of 9900 lb. per sq. in. in tension in the outside fiber of the cylinder was found. The thickness of the above cylinders was 2½ in., while that of the test cylinder was 2 in. The probable maximum initial stress of the hydrostatic test cylinder was about 7900 lb. per sq. in. In the third place the static, elastic and fatigue results in the metal which had been subjected to the hydrostatic fatigue test is lower in every case than that of the metal taken from the same plate which had not been so tested.

In the first case the impressed stresses during the hydrostatic test was equal to or above the direct stress endurance limit of the metal. In the second case the initial stresses present in the outside layer of the test cylinder raised the impressed stresses considerably above the direct stress endurance limit, and in the third case, the effect of breakdown in the metal as between that used in the original hydrostatic test and that left over from the same plate but which was not a part of the original test, is shown by a general decrease of static elastic and fatigue strength values obtained under subsequent tests.

In tests previously made at the University of Illinois on specimens which had been subjected to a certain number of fatigue stresses above the endurance limit and subsequently determining the endurance limit of such overstressed metal, it was found that overstressing for 5000 cycles 35.0 per cent above the original endurance limit decreased the subsequent endurance limit of such specimens by about 11.0 per cent.

SUMMARY

The endurance limit of the metal in direct stress in the cylinder before it was subjected to the hydrostatic fatigue test is estimated from actual endurance limit tests in the rotating beam machine to be about 20,600 lb. per sq. in. The actual maximum stress to which this metal was subjected in the hydrostatic fatigue test was somewhere in the neighborhood of 22,500 + 7900 lb. per sq. in. or 30,400 lb. per sq. in.

The flexure endurance limit of the metal in the cylinder after it was subjected to hydrostatic fatigue was found to be 28,000 lb. per sq. in. The flexure endurance limit of the metal from the same plate but which had not first been subjected to the hydrostatic fatigue test was found to be 31,000 lb. per sq. in. This shows that

the hydrostatic test had overstressed the metal and had thereby reduced the flexural endurance limit 9.7 per cent.

The test specimens were not selected from near the fracture of the cylinder because it was thought that the fracture had extended into the adjacent metal to such an extent that the subsequent tests would have been erratic and no stable conclusions therefore could have been drawn from them. This was assigned as the reason why the static ultimate strength values did not show a larger percent decrease from the values given by the virgin metal.

T. McLEAN JASPER,
Univ. of Illinois.

INVESTIGATION OF THE FATIGUE OF METALS

UNIVERSITY OF ILLINOIS
Urbana

January 5, 1926.

Mr. C. C. Joys, Jr.,
A. O. Smith Corporation,
Milwaukee, Wis.
Dear Sir:

Referring to my report of November 23, 1925, made on the steel taken from the penstock demonstration test vessel, there is no doubt that the fact that the vessel was unannealed resulted in initial stresses of considerable magnitude being present in the material, which stresses were in addition to those impressed by the test. These stresses calculated from subsequent tests on similarly welded vessels were undoubtedly in the neighborhood of 8000 lb. per sq. in. I am convinced that proper normalizing or annealing would have reduced such initial stresses to a negligible quantity.

Tests already performed by the writer show that when initial stresses are present in a metal to the extent of about 35,000 lb. per sq. in., annealing has relieved these stresses to such an extent that their importance is less than the fluctuation found in the ultimate strength values on adjacent metal in a plate. These results were presented in a paper read before the British Association and published in London "Engineering" of Sept. 5, 1924.

The above remarks refer to penstocks and vessels which are to be used at ordinary temperatures.

It is the opinion of the writer, based on experiments now in progress, that annealing is not necessary where vessels are to be used at or above 600 deg. F. for the reason that the very conditions of operation has the effect of annealing the material in such vessels.

Yours very truly,
T. M. JASPER,
Special Research Associate Professor of Engineering Materials.

TMJ:EW

Report on Penstock Demonstration Test

Conducted by A. O. Smith Corporation, Milwaukee, Wisconsin, on October 11-12-13, 1925.

Waterhammer has proven to be most disastrous to penstocks, and to imitate such shocks a testing machine was devised and built. With this machine a vessel could be subjected to repeated shocks of variable intensity and the effect of these shocks studied.

THE VESSEL used for the demonstration test was made up of a cylindrical section 45 in. inside diameter, 2 in. wall and 8 ft. long. Both ends were closed with hemispherical heads of high grade cast steel, 4 in. thick, making the overall length of the

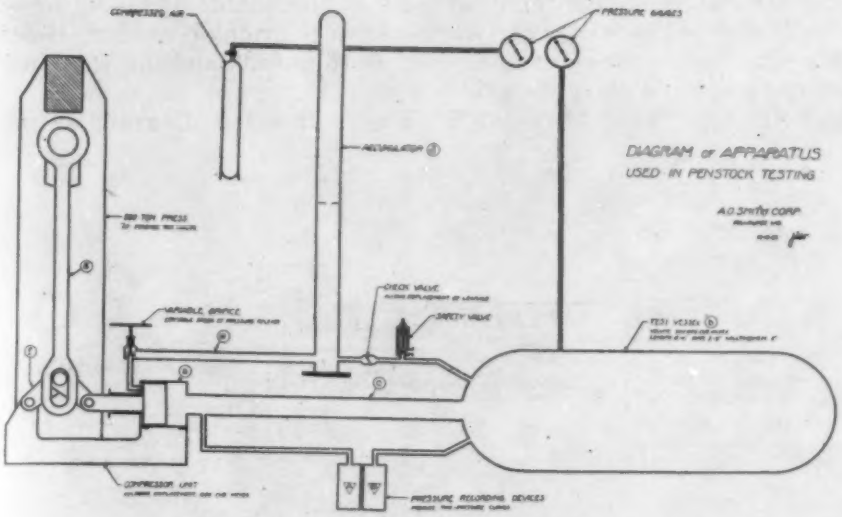

Fig. 1—Equipment Used In Test

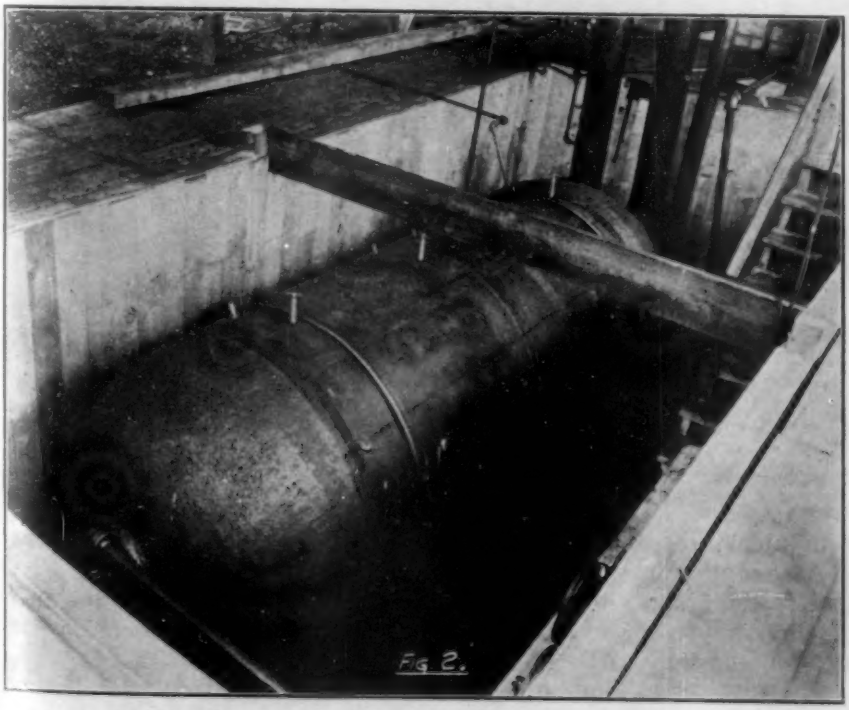

Fig. 2—Vessel Placed In Pit Ready for Testing

vessel 12 ft. The shell was built up of formed plates so as to necessitate one circumferential weld in the center and four longitudinal welds (see Fig. 2). All joints were machine welded. Holes for pipe connections were provided in the heads and the shell had six tapped holes along its axis for petcocks.

THE TESTING MACHINE. Fig. 1 shows a diagram of the

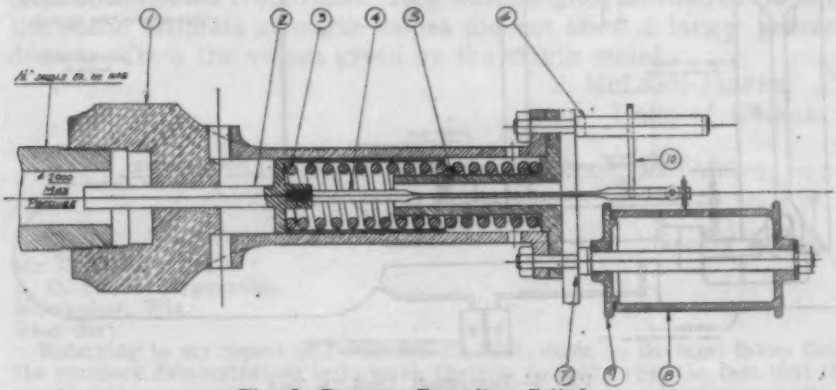

Fig. 3—Pressure Recording Cylinder

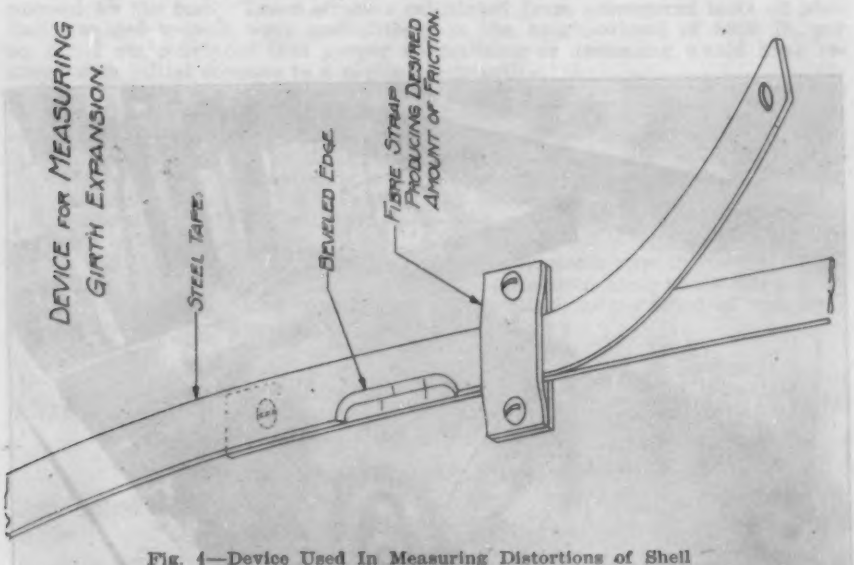

Fig. 4—Device Used In Measuring Distortions of Shell

equipment used for the test. The principle is as follows:

A Compressor (a) is used for effecting the pressure rise. The test vessel (b) is by means of a pipe (c) connected with one end of the compressor cylinder, the other end being connected with an accumulator (d) by means of a pipe (e).

The test vessel, both pipes and the cylinder as well as half the accumulator is filled with water under a certain pressure with the

piston in the position shown. When the piston moves forward the water in the vessel will be compressed, raising the pressure to a predetermined maximum while the water in pipe (e) follows up, approximately maintaining the original pressure due to compressed air in the accumulator. The piston gets its motion from a toggle arrangement (f) with adjustable stroke and actuated by a slotted connecting rod (g) on the crank of a 50 ton press. Consequently the piston is moved forward at a speed controlled by the crank, but after the toggle has passed the straight position the slot in the connecting rod allows the toggle to collapse which permits the piston to snap back. In other words, the pressure is gradually built up

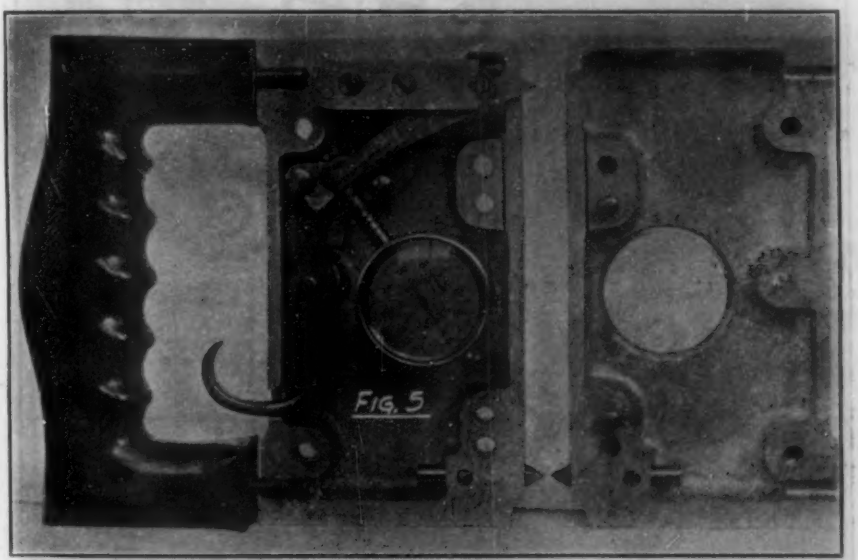

Fig. 5—Extensometer for Measuring Expansions

from a min. to a max. and then suddenly, (in less than 0.15 sec.) made to drop back to the min. where it remains constant for the last portion of the stroke. The energy, suddenly released at the pressure drop, is absorbed by wire-drawing the water thru an adjustable orifice in pipe (e), and to prevent the piston from hitting the bottom of the cylinder a choking pin, like in a dash pot, is provided. Thus the action of the machine can be perfectly controlled and a wide latitude of test pressures obtained. The pipe (c), leading from the cylinder to the test vessel, is made very large in diameter so as to reduce the velocity of the water column to a minimum. This velocity would otherwise reach dangerous proportions. The same holds true about the pipe (e), leading from the cylinder to the accumulator. As a precaution, however, both pipes were securely anchored to each other and to the floor in two places. Besides furnishing the backpressure the accumulator also

serves to replace water lost from the vessel side of the piston due to leakage. For that reason the accumulator is connected to the test vessel with a pipe and backflow during pressure rise is prevented by a check valve in this line. Provision is made for main-

Fig. 6—Compressor Unit

taining desired air pressure in the accumulator, also for pumping water into the system, and in a number of places plugs and petcocks make possible the elimination of all air in the system.

Instruments.—Pressure gauges were connected to the test vessel and the accumulator and, together with other instruments, located

alongside the machine. These instruments consisted of pressure recording cylinders (Fig. 3) attached to a standard Tachograph with motor drive. It was thus possible to obtain time-pressure curves at any moment desired.

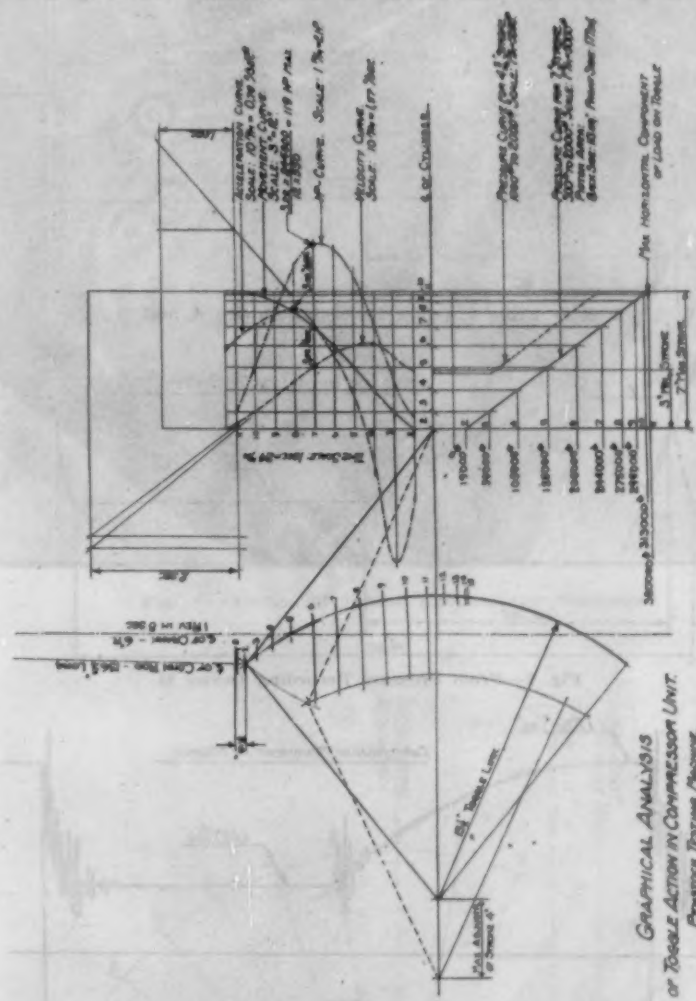

Fig. 7—Important Note: Original Drawing Reduced One-Half, Therefore Readings From Scale Should Be Changed Accordingly

To record the changes taking place in the test vessel itself during the experiment special arrangements were made. Elongation of the cylindrical shell was measured in one place and expansion of the girth in three places. Fig. 4 shows the device used for these readings, a steel band held securely at one end and the other end free to slide with some resistance. The approximate location of these instruments is made clear on Fig. 2.

To make a further study of the expansions, provisions were made to use an Extensometer as shown on Fig. 5.

General Arrangement.—The compressor unit in the press is shown on Fig. 6, which also indicates the general arrangement of the equipment within the building. The test vessel itself with accumulator and piping was mounted on a structural steel frame which was placed in a pit outside of the building (see Fig. 2).

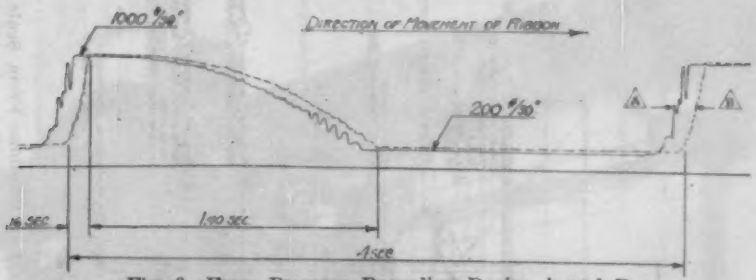

Fig. 8—From Pressure Recording Device A and B

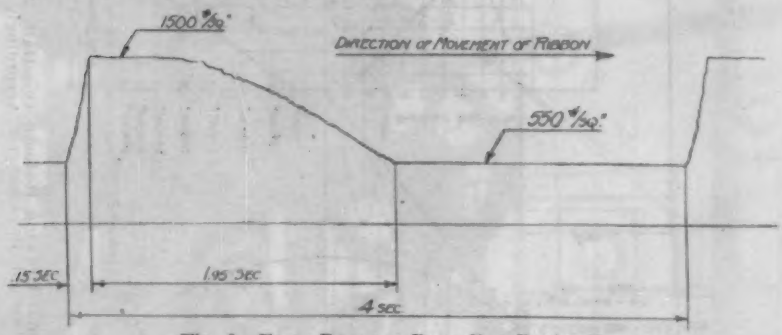

Fig. 9—From Pressure Recording Device B

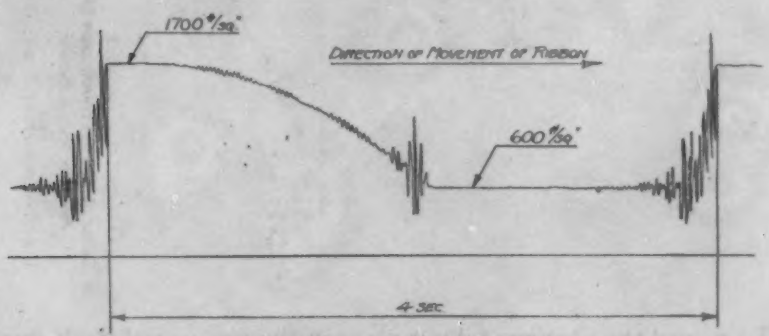

Fig. 10—From Pressure Recording Device A

Figs. 8, 9 and 10 Are Time-Pressure Curves. Time Scales 1 mm.=.0475 Sec. Pressure Scales 1 mm.=66.25 Pounds per Square Inch

The action of the compressor unit is made clear on the Diagram, Fig. 7, where time-velocity and time-power curves are plotted for various combinations of stroke and pressure. It will be noted that two shocks are obtained during each cycle of the crankshaft or about 15 shocks per minute.

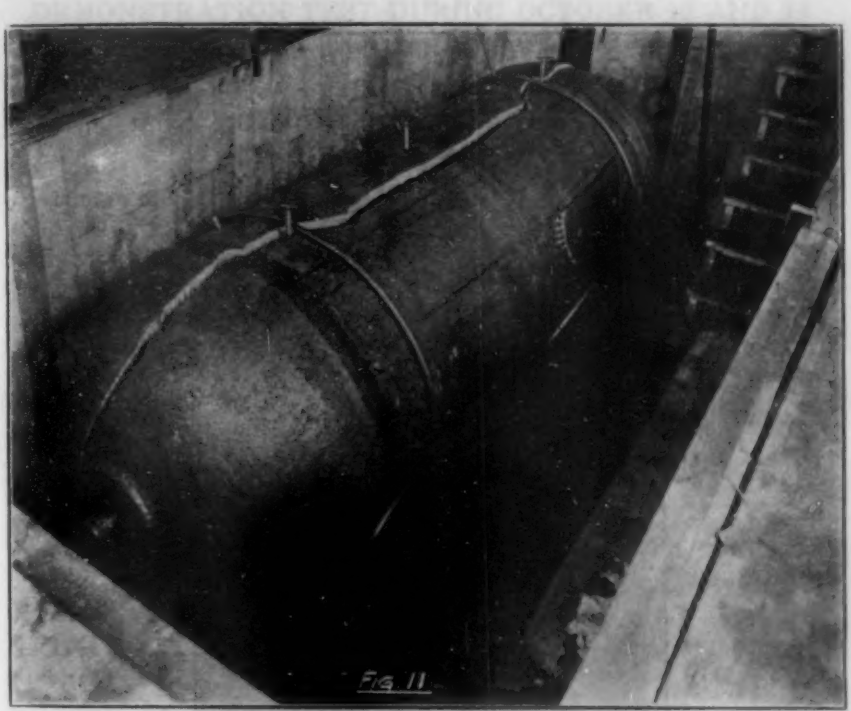

Fig. 11—Method of Taking Extensometer Readings

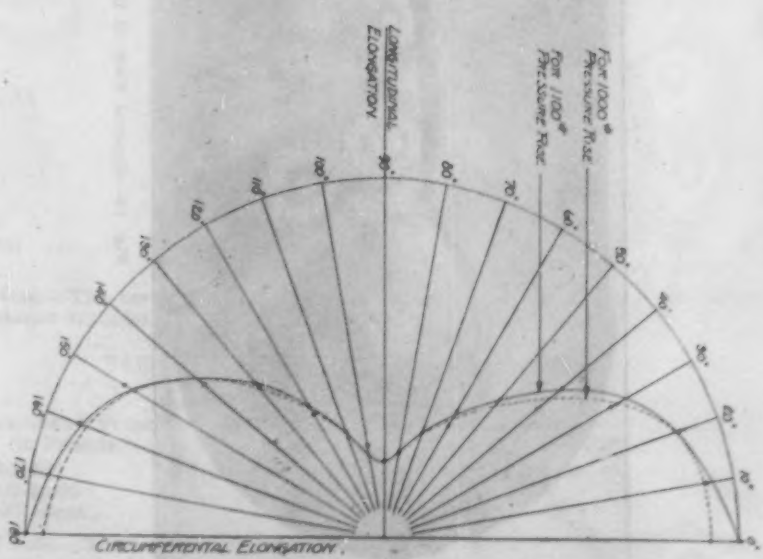

Fig. 12—Extensometer Readings Plotted in Polar Coordinates; Curves Representing Elongation in 6 In. Scale 10 mm.=0.000425 In.

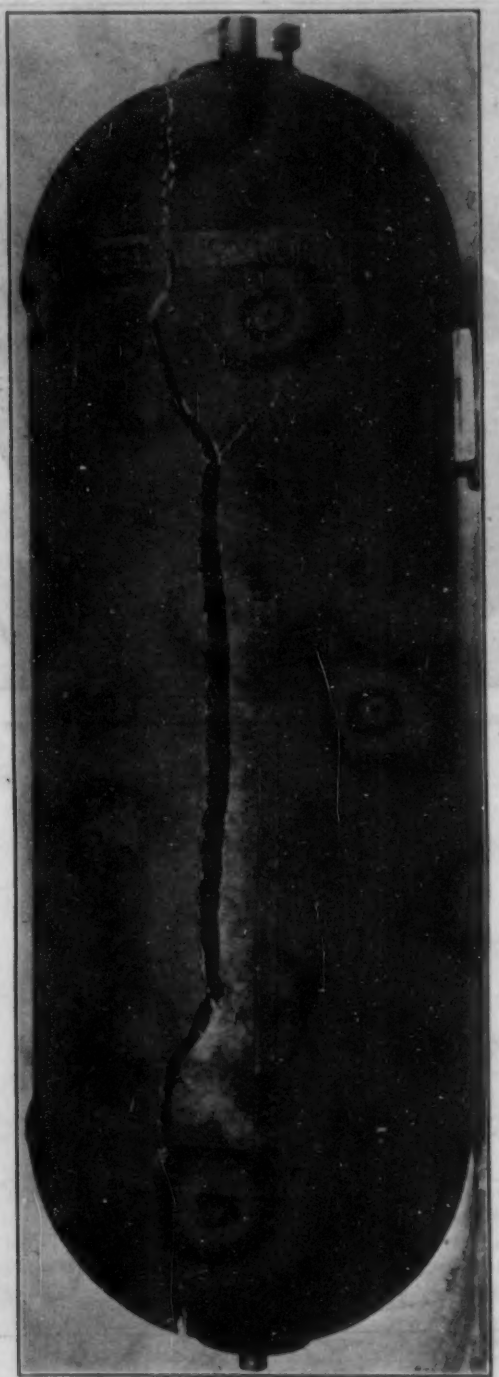

Fig. 13—General View of Break After Fatigue and Static Destructive Test

DEMONSTRATION TEST DURING OCTOBER 12 AND 13

After a short trial run on Oct. 11, the actual test was started Oct. 12. As the summary below indicates, the initial or accumulator pressure as well as the peak pressure was varied, but 72 per cent of the test was carried on at 2000 lbs. peak pressure. (Refer Table No. 1).

At intervals readings were taken on the recording devices. Figs. 8-10 inclusive show typical records of these readings.

Measurements of the longitudinal and girth tapes were taken on three occasions. The results will be found in the table below. The two first measurements were taken while the load was being applied in shocks, as described below, and it was found that no permanent expansion took place. On the third occasion the vessel was under a steady load, preparatory to the destruction test. (See Table No. 2.—Elongation on Test Vessel.)

TABLE 1—SUMMARY OF TEST PRESSURES, ETC.

	Actual Running Time in Minutes	Accumulator Pressure, Pounds	Peak Pressure, Pounds	Duration of Test in Minutes	Actual Running Time in Minutes	Shut Down, Time in Minutes	Number of Shocks
Oct. 12	25	250	1,000				350
	8	500	1,300	70	53	17	112
	20	1,000	2,000				280
Night, Oct. 12 and 13 ..	10	500	1,300				140
	17	1,000	2,000				238
	10	1,000	2,000				140
	5	500	1,300				70
	10	1,000	2,000	635	267	368	140
	60	1,000	2,000				840
	50	1,000	2,000				700
	20	500	1,300				280
	85	1,000	2,000				1,190
Oct. 13	10	500	1,300				140
	9	800	1,900				126
	57	900	2,000	305	140	165	798
	19	500	1,200				266
	30	700	1,700				420
	15	1,000	2,000				210
Total				16 hr. 50 min.	7 hr. 40 min.	9 hr. 10 min.	6,440

Note.—The test was interrupted several times in order to allow correction of minor troubles.

TABLE 2—ELONGATIONS ON TEST VESSEL*

Pressure on Vessel in Pounds	Longitudinal Tape Full Length of Shell	West End Girth Tape	Center Girth Tape	East End Girth Tape
200-1,000	Not noticeable	1/16"	3/32"	1/16"
1,000-2,000	1/64"	3/32"	7/64"	5/64"
2,500 const.	1/32"	9/64"	1/8"	5/64"

*Note.—The tapes were intended to be used during the destruction test and, as comparatively large readings were expected, scale measurements were considered adequate.

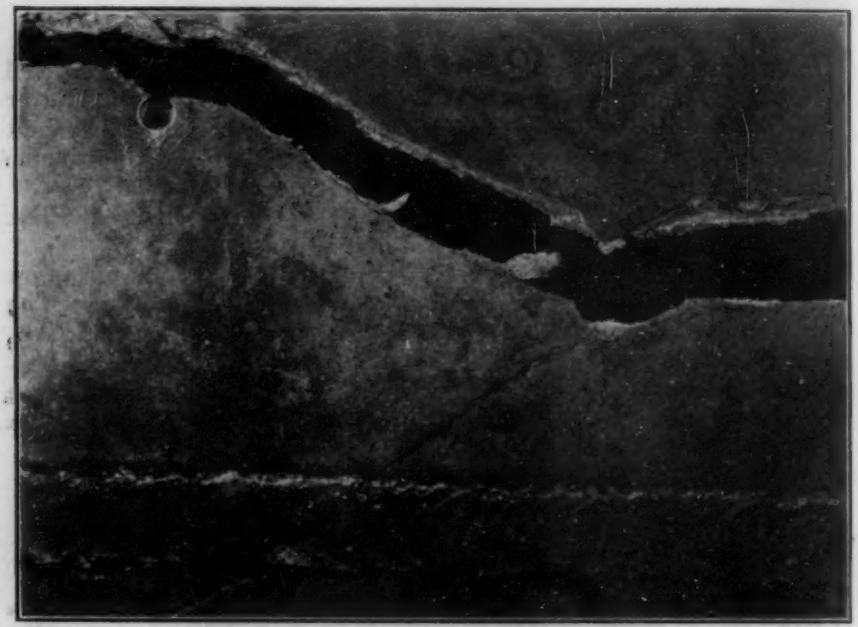

Fig. 14—Break, West End

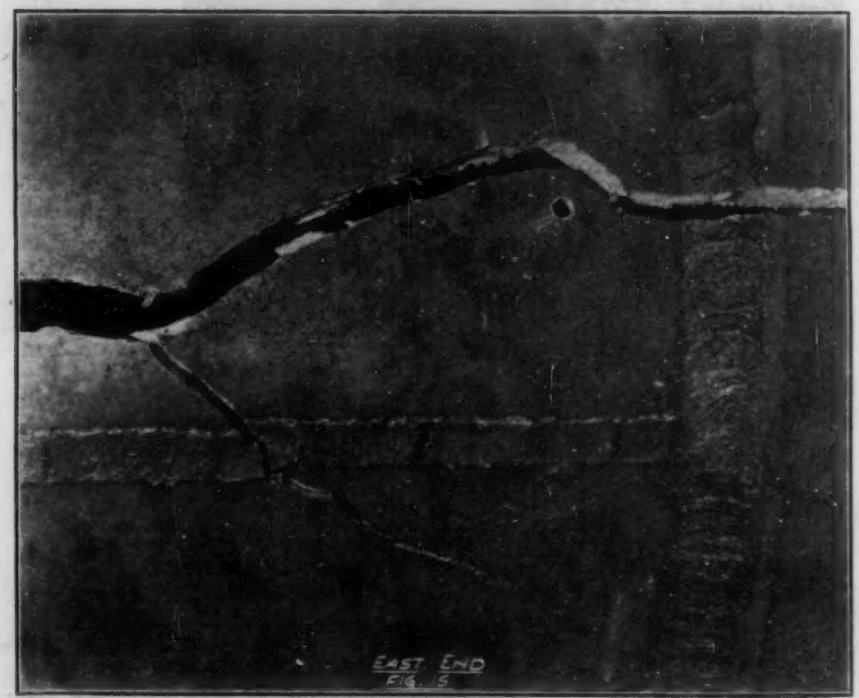

Fig. 15—Break, East End

A special series of tests was made while the machine was in operation, using the Extensometer shown on Fig. 5. Readings were taken under various pressures parallel with and at right angles to the axis of the vessel as well as at every 10° between these two positions (see Fig. 11). The distance between points was 6 in., and on account of its shortness compared to the diameter of the vessel no attempt was made to correct for the curvature of the surface. The readings are tabulated below, each one being checked over a series of shocks while the pressure rise was maintained uniform. It was noted that in no case did any noticeable part of the elonga-

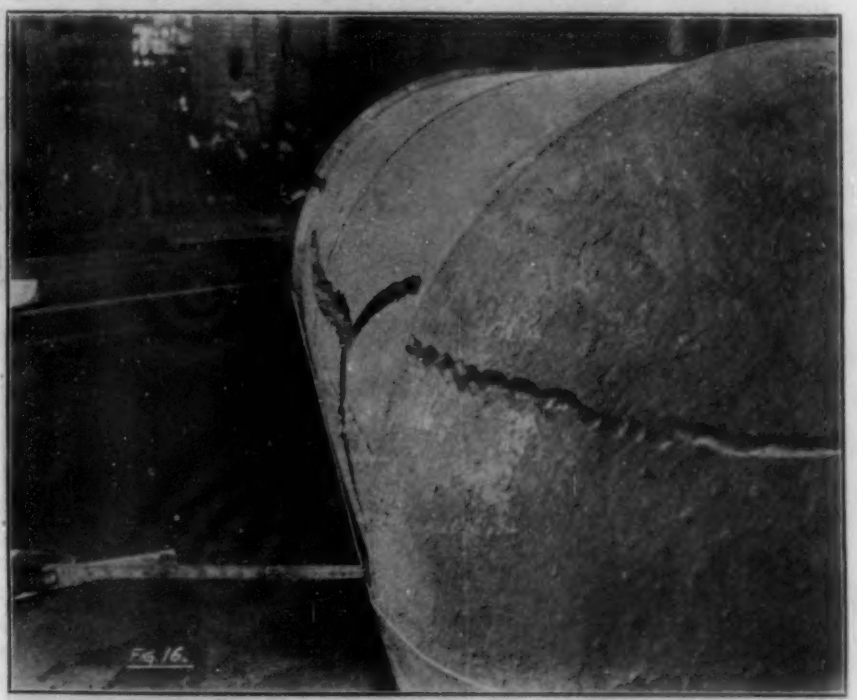

Fig. 16—General View Showing Bulging of Tank

tion become permanent, indicating that for these test pressures the elastic limit was not exceeded.

EXTENSOMETER READINGS: (IN $\frac{1}{30{,}000}$ in. IN 6″ GAUGE LENGTH)

Pressure in Pounds	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
400–1,500	56	56	55	46	35	30	25	20	14.5	13
600–1,700	61	56	54	45	40	31	22	19	15	13

	100°	110°	120°	130°	140°	150°	160°	170°	180°
400–1,500	14	19	24	34	40	49	55	61	58
600–1,700	16	18	26	33	40	51	55	58	61

The findings of this experiment, as contained in Table No. 3,

are also shown graphically on Fig. 12, the curves being plotted in polar coordinates.

In all, the test vessel was subjected to about 7000 shocks during nearly 8 hours of actual running time. At the end of this experiment there was no apparent defect in either the welds or the plate.

The fatigue or shock test being brought to a satisfactory conclusion, the plans called for a final Destruction Test of the vessel. All pipes were disconnected except the ones leading to the pump and the pressure gauge, and all openings plugged up. The test pit was then covered with planks weighted down by sand bags. When the vessel was properly filled with water and all air removed the pressure was gradually raised until 2500 lbs. was reached.

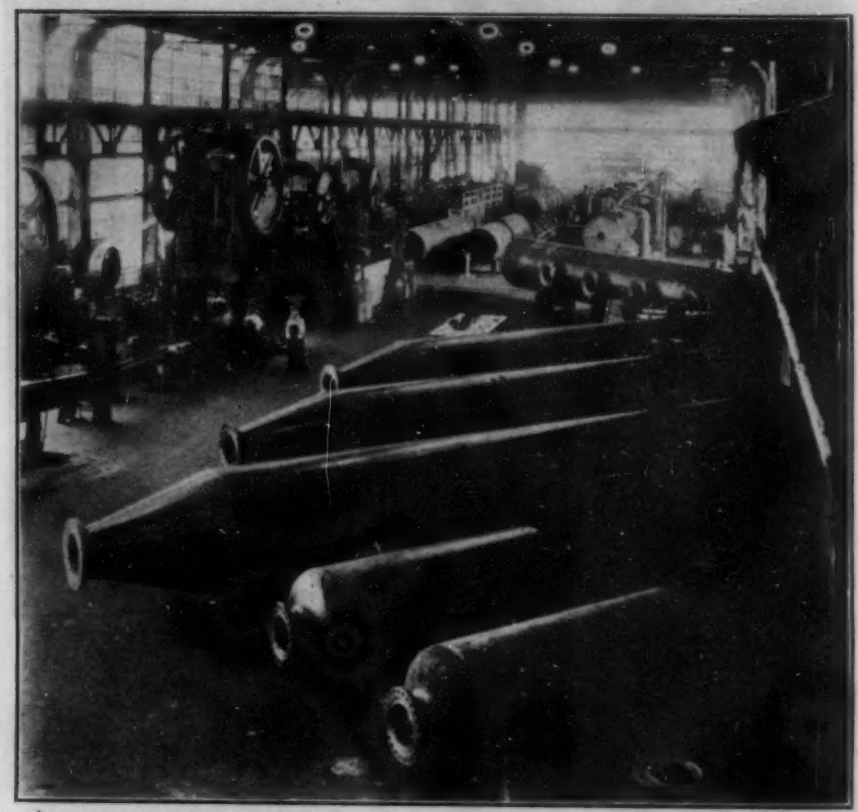

Fig. 17—Gasoline Cracking Stills Manufactured by A. O. Smith Corporation

Here the pump was stopped and the pressure relieved for a few minutes while the last readings on Table No. 2 were taken. The pumping was then resumed and at about 2700 lbs. sq. in. the vessel burst along its full length as shown on Fig. 11. In no place did the crack run along a weld (see Figs. 13-16 incl.), and the welds

seemed to have no influence on the location or direction of the fracture. It will be noted that the center portion show a considerable bulging out (see Fig. 16). Outside of the main longitudinal fracture which branched out at the ends, two circumferential cracks appeared near the center of the vessel. All fractures showed a very coarse grain.

CONCLUSION:

It is evident that in the shell, which was not annealed, certain initial stresses remained after welding. The outside of the shell

Fig. 18—Visitors Witnessing Tests

must have carried tension of appreciable magnitude while the inside suffered under equally high compression. Recent observations substantiate this theory. That being the case it is obvious that a sudden shock given to the vessel will relieve the stresses in the inner layer up to the neutral axis and add to the stresses in the outer layer, possibly exceeding, or at least approaching the elastic limit in the extreme outer fibres. Repeated shocks are then apt to break down the resistance of the outer layers, whereas a slowly rising dead pressure might have allowed the material to stretch and gradually bring the entire section in action. Previously conducted bursting tests substantiate these assumptions as well as the conclusion that the Fatigue test broke down the strength of the vessel, and that this alone was responsible for the low ultimate resistance offered by the vessel used in this test.

Effect of Heat of Bronze Welding on Cast Iron Pipe*

ARTHUR R. LYTLE†

The bronze welding of cast iron and steel has been a recognized commercial process for a matter of two years only, yet in that time it has developed from a little known novelty to a wide spread and much relied upon process of uniting metals. Its most important application by far has been in connection with cast iron welding, particularly in the construction of pipe lines of cast iron, although its applications are rapidly spreading to general repair work of all kinds.

Our interest at the present, however, is concentrated on the bronze welding of cast iron pipe. The most notable advantages of this process over that of actual welding with a cast iron welding rod are first, the shorter time required for the weld, and second, the lower temperature at which the welding proceeds. This last permits the welding to be done successfully on unpreheated sections as the contractions of the weld and base metal are slight and the stresses set up by the cooling may be absorbed by the ductile bronze. To the above advantages should be added the all important one that the strength of the bronze is greater than that of the cast iron.

The bronze welding of cast iron pipe has gradually become an art separate from all other bronze welding processes. Many miles have been successfully laid using bronze welding as the only method of uniting the pipes. In these lines, there are two types of cast iron pipe, one the sand cast pipe and the other a centrifugally cast pipe. The latter pipe seems to have come into its own for bronze welding for, as explained later, as the material is of more compact structure and more uniform strength, and also stronger than the sand cast iron pipe, it is possible to use thinner walled pipes than previously. These thinner gage materials lend themselves to welding much more readily than to other means of uniting.

In the course of the application, testing, laying and use of these bronze welded pipe lines, a certain number of failures have occurred both in the bronze weld and at some distance from it. Various theories as to the cause of these failures have been advanced. With some of these, particularly those that deal with the residual and other stresses, we are not at this time interested except in so far as to say that if they are true of bronze welded joints, they apply even more forcibly to other types of welded joints. We are interested only in the theories that depend on the structural changes that occur in the cast iron due to the heat of the application of the bronze.

Some work has been done on this by several metallurgists, par-

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ticularly of companies for whom the welding was being done. Several of these reports have been published and as the conclusions in them do not agree in all cases with our observations, we have thor-

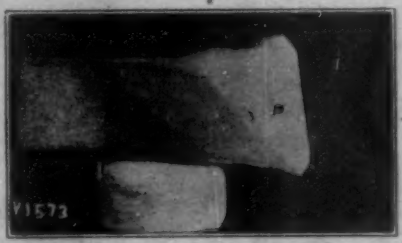

Fig. 1. Full size etched section through cast iron weld in sand cast pipe. The weld metal is the light area on the right.

oughly investigated a number of such welds and the following is a description of our work and findings.

It seemed advisable, at the start, to include a study of the cast iron welding of cast iron pipes also as not only would the informa-

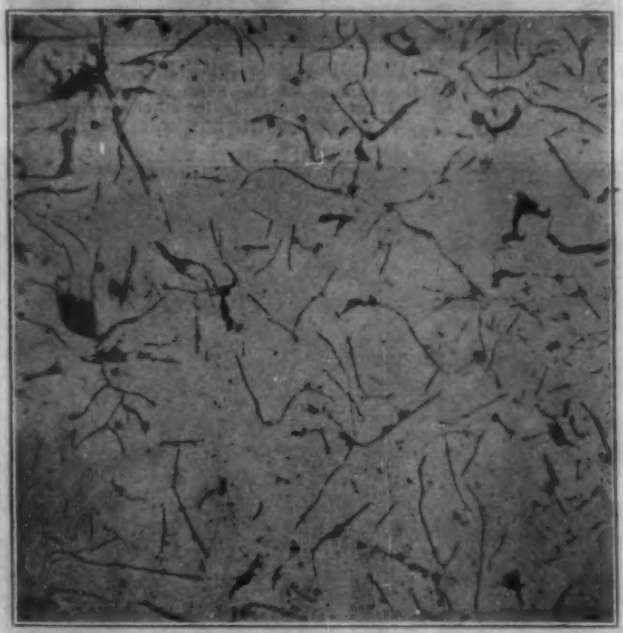

Fig. 2. Average distribution of the graphite plates in the sand cast pipe. Unetched. 100X.

tion be valuable but the broader field of work would facilitate the elucidation of the various structures. Also we are not aware of any such work having been published.

For the benefit of those who are unfamiliar with the constituents of cast iron, it may be well to describe briefly the various constitu-

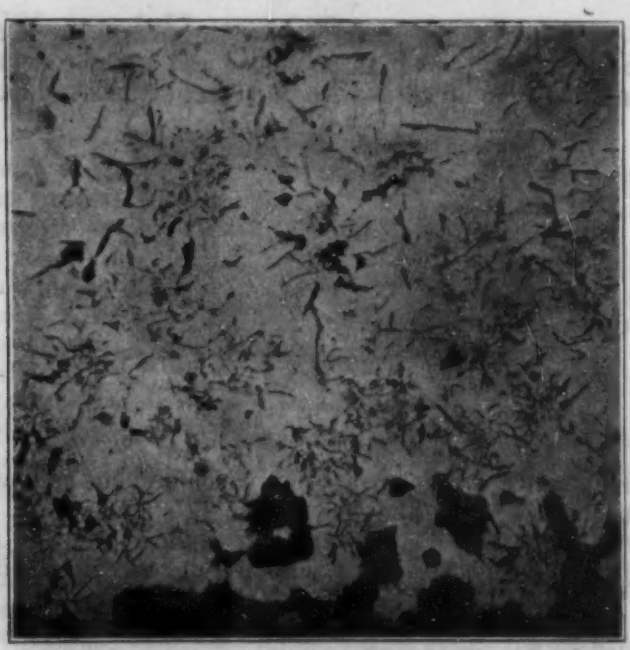

Fig. 3. Unetched. Average view of the distribution of the graphite plates at the surface of the sand cast pipe. The surface is ragged and the graphite is in starlike clustors. 100X.

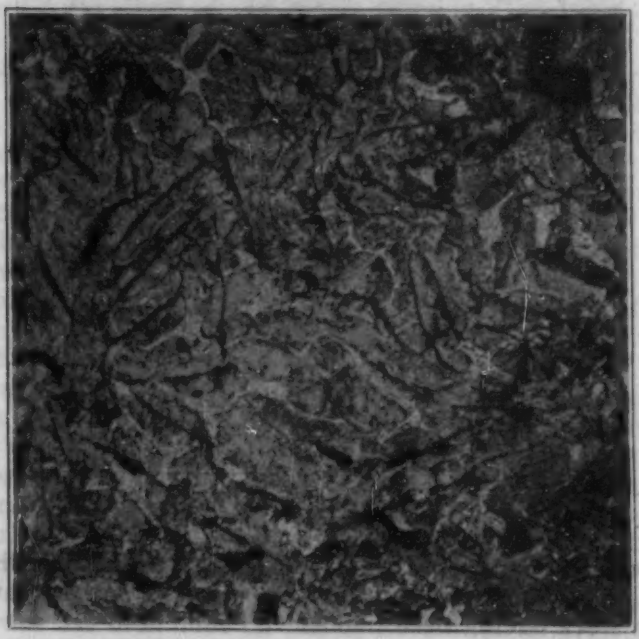

Fig. 4. Average view of the base metal after etching. The structure is uniformly pearlitic. The white pattern is the phosphide eutectic. 100X.

ents to which allusion will be made. For practical purposes, cast iron is merely steel containing more or less graphite or free carbon. Of course, other elements, silicon; sulphur, phosphorous, and manganese, also exist in larger percentages than in steel, but they may be dismissed for the present.

As in steel, the mass of cast iron may consist of any one of three mixtures, depending on the chemical composition and the rate of cooling when cast. These possibilities are:

First: Perrite and pearlite.
Second: All pearlite.
Third: Pearlite and free cementite.

Of these, the first is the most common, the second is occasionally found and the third is rare, being found in white irons only. Another possibility is that the pearlite may be entirely absent, but this is usually caused by unusual conditions such as a peculiar chemical composition or exceedingly slow cooling.

The free carbon exists in flakes and is referred to as graphite. Inasmuch as these flakes of graphite are well distributed throughout the mass of the usual cast iron and also as they have no strength, they greatly reduce the strength and ductility of the metal. In fact, the strength and ductibility of cast iron is almost entirely dependent on the size, amount and distribution of the graphite plates. In the case where the mass of the cast iron is nearly all ferrite, the graphite plates would usually be long and thick, producing a weak iron. Under other conditions, it would be possible to produce a pearlitic or partly pearlitic mass, but if the graphite plates were the same as in the first example, the physical properties would not have been increased materially. The smaller the size of the plates and the less the amount, the greater will be the strength of the cast iron. For this reason, in examining cast iron, it is always necessary to inspect the specimen closely for any areas in which the graphite flakes might be in abundance for at such a place the physical properties would be low. The usual result of heat treatment is to affect principally the condition of the combined carbon in the pearlite, possibly transforming it to sorbite or the other variations that occur in steel.

One other constituent of cast iron is important. If phosphorus be present in sufficient amount, it forms with ferrite a constituent called iron phosphide and this in turn, unites with iron carbide and free iron to form an eutectic termed the phosphide eutectic. This constituent is readily distinguished by its peculiar appearance. It is brittle and if in abundance, leads to low physical properties of the iron. As it does not change form or composition upon heating up to its melting point, it is not possible to alter the location or distribution of this constituent to any determinable degree by heat.

The other elements, unless in excess, do not enter into the structural details of cast iron except possibly as non-metallic inclusions, so they have no bearing in the present discussion.

After this brief explanation, it might be well to describe in a gen-

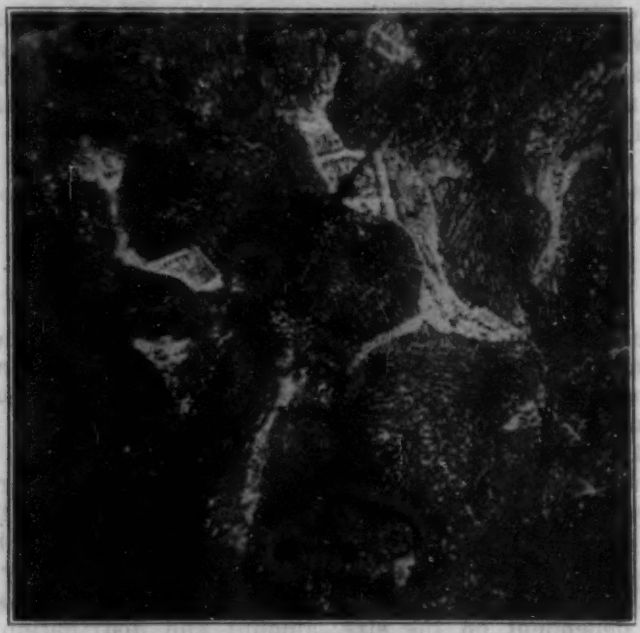

Fig. 5. View of the base metal showing that it is pearlitic. This also shows the typical dotted structure of the phosphide eutectic. 430X.

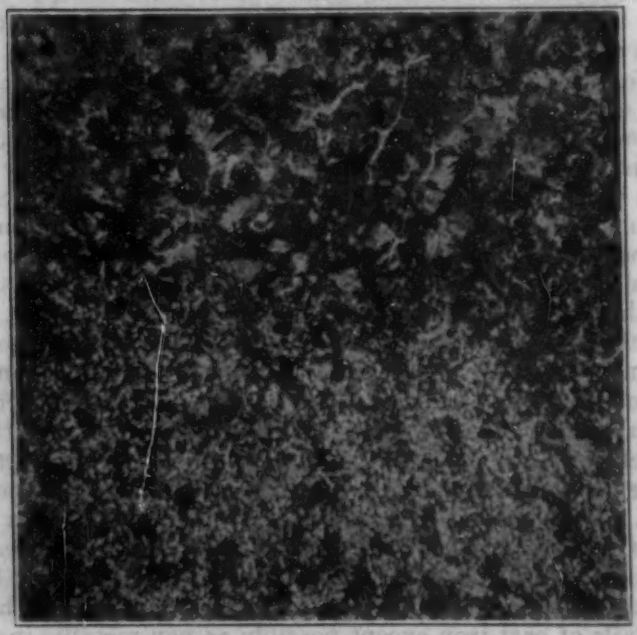

Fig. 6. View at the line of the weld. The weld metal below is fine grained and well united to the base metal above. 100X.

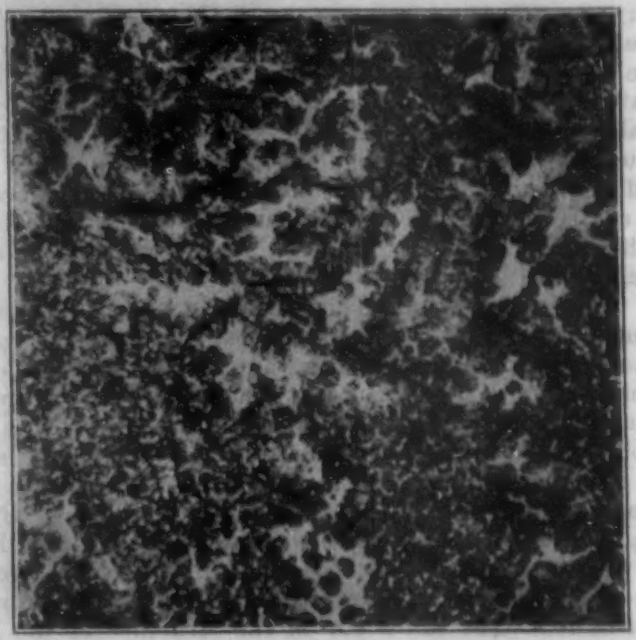

Fig. 7. Average view in the heat affected area of the base metal. The ground mass has become sorbitic. 100X.

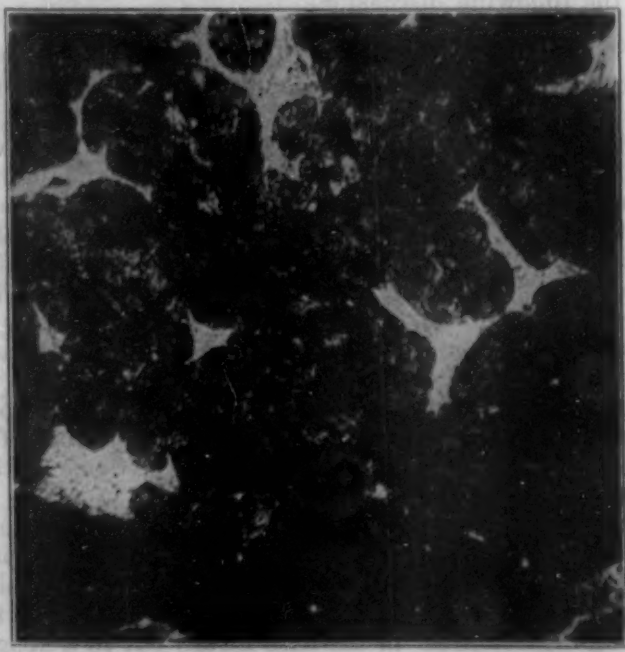

Fig. 8. View of the heat affected base metal showing the sorbitic structure. The phosphide has been unaltered by the heat. 430X.

eral way the differences between the two types of pipes. The usual sand cast pipe is cast in a dry sand mold and receives no other material treatment. It is usually of good quality cast iron with moderate size graphite plates and a pearlitic ground mass, its physical properties being those of a fine grained cast iron. The centrifugal cast iron pipe is made by pouring molten cast iron into a rapidly revolving cylindrical chill mold. The thickness of the pipe is controlled by various operating conditions. On being drawn from the mold, the chill casting is passed through an annealing furnace, where it is heated slowly to 980 deg. C. or about 1600 deg. F. and then slowly cooled. This chilling and controlled annealing distributes the graphite in fine particles rather than in long flakes. This cast iron is stronger, tougher, and more ductile than the sand cast iron and consequently the pipes may be of lighter section.

The cast iron and bronze welding of these two types of pipes offer four varied, yet closely allied, series of changes in structure. In cast iron welding the base metal is actually remelted, the adjacent material being subjected to temperatures varying from room temperature to the melting point of cast iron. On the other hand, bronze welding is done at a temperature at which the iron is just a dull red. This lower temperature not only lessens the number of transformations that can occur in the structure of the iron, but also shortens the time in which those that can occur may be effective. The results of the varying influences will be clearly evident in the following discussion.

Cast Iron Welding of Sand Cast Pipe:

Fig. 1 is a view of a section through the weld in this material and shows the presence of four distinct areas, namely, the unaltered base metal, two zones in the heat affected area, and the weld metal. The photomicrographs given in Figs. 2 to 10 explain the alterations and variations in the structures of the different zones more clearly than they can be described. The original metal has the usual distribution of the graphite as long flakes in the interior, although close to the surface it assumes a starlike form. The etched structure, Figs. 4 and 5, show that the metal is entirely pearlite, phosphide eutectic and graphite, there being no visible amount of free ferrite.

The weld metal is quite uniform in structure, resembling that at the bottom of Fig. 6, a fine grained, uniform mixture of pearlite, phosphide eutectic and minute graphite flakes. Some of the larger of these flakes are shown in Fig. 10.

A thorough examination was made at all points in the heat affected area for any alteration in the distribution or amount of the graphite that might lessen the strength of the material, but no such change was found. The graphite in the middle of this area seemed slightly less than in the base metal, but in a space within 1/100 in. of the scarf where it might be expected that any accumulation of graphite would occur, the distribution and amount were

the heat. 480X.

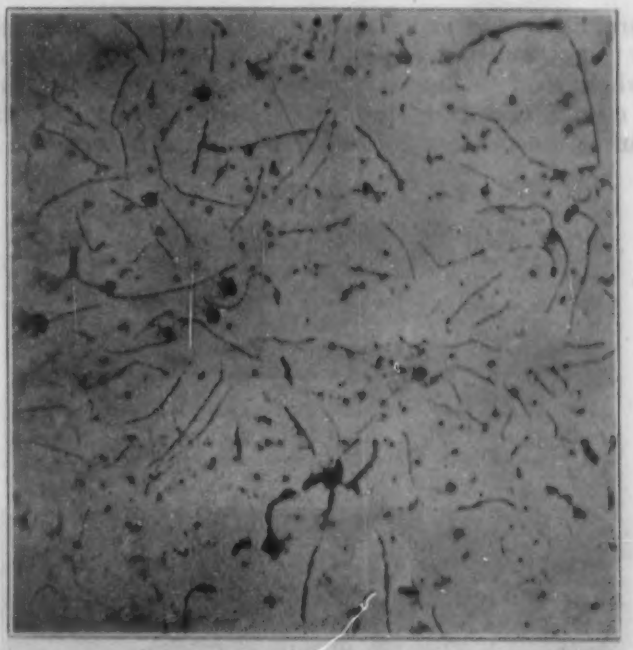

Fig. 9. Average view of the distribution of the graphite plates along the vee in the base metal. It is about the same as in the original base metal shown in Fig. 2. Unetched. 100X.

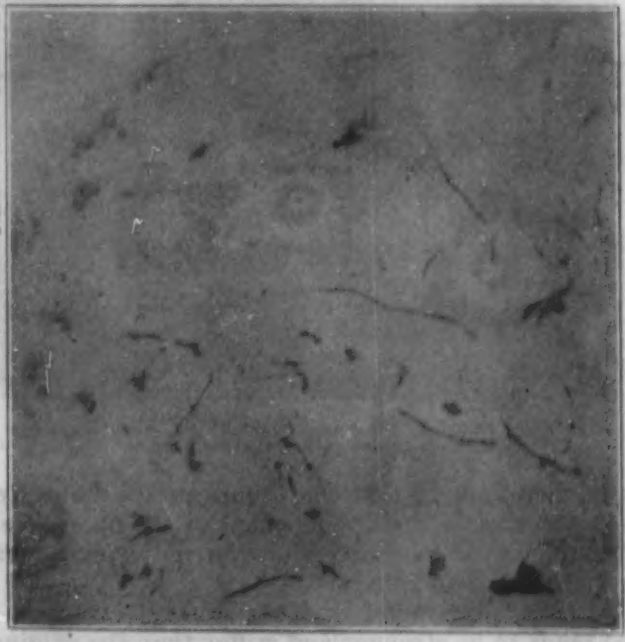

Fig. 10. View of a few of the graphite flakes in the weld metal, indicating their size and distribution. Unetched. 480X.

found practically the same as in the base metal. The effect of the heat on the other constituents of the iron are the usual ones that occur when steel is heated above the critical points and rather quickly cooled, that is a slight refinement of the grain and some reversion of the pearlite into finer pearlite and sorbite.

Fig. 11. Full size etched section through a cast iron weld in centrifugal cast iron pipe. The weld is on the left.

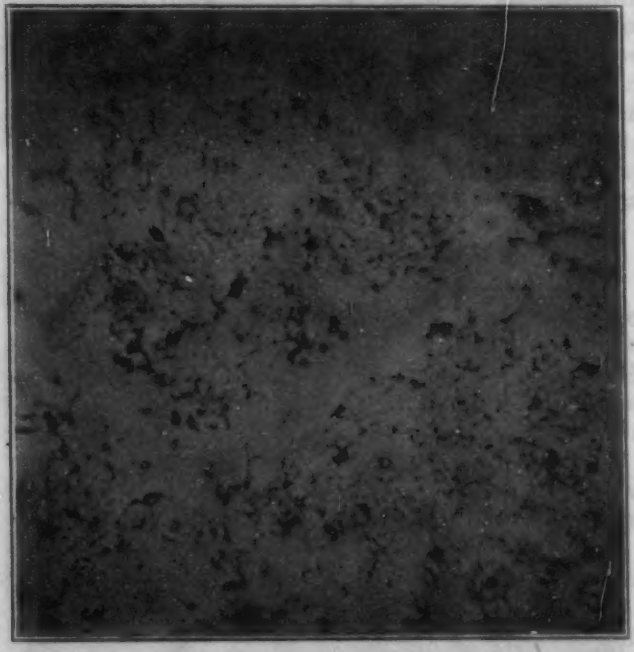

Fig. 12. Unetched. Average view of the distribution of the graphite flakes in centrifugal cast iron. 430X.

It was further thought that the failure of the welded cast iron might be due in part to a rearrangement of the phosphide eutectic under the influence of the heat. However, no evidence was found to substantiate this possibility.

In fact, it has been found that, structurally, the heat affected base metal tends to be stronger and stiffer than the original metal. Also, due to the more rapid cooling and finer graphite flakes in the

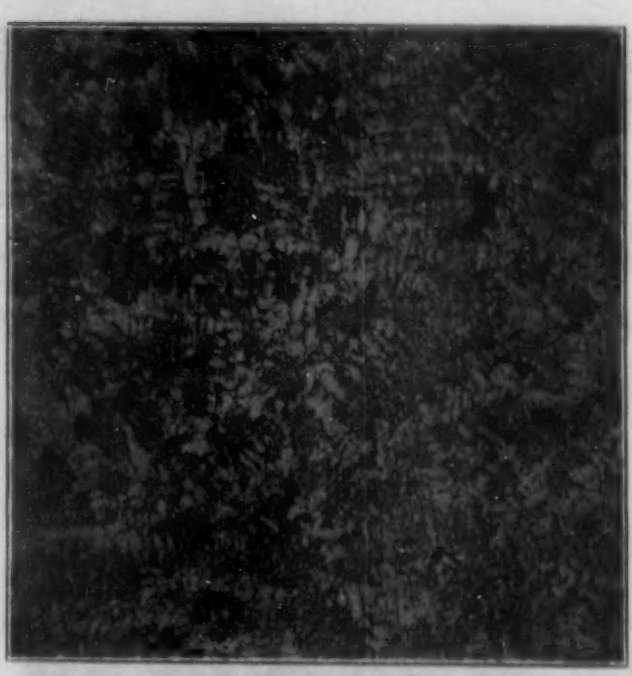

Fig. 13. Average view of the etched base metal. The darker areas are the clusters of graphite, the white areas are ferrite. The phosphide eutectic is in minute patches. 100X.

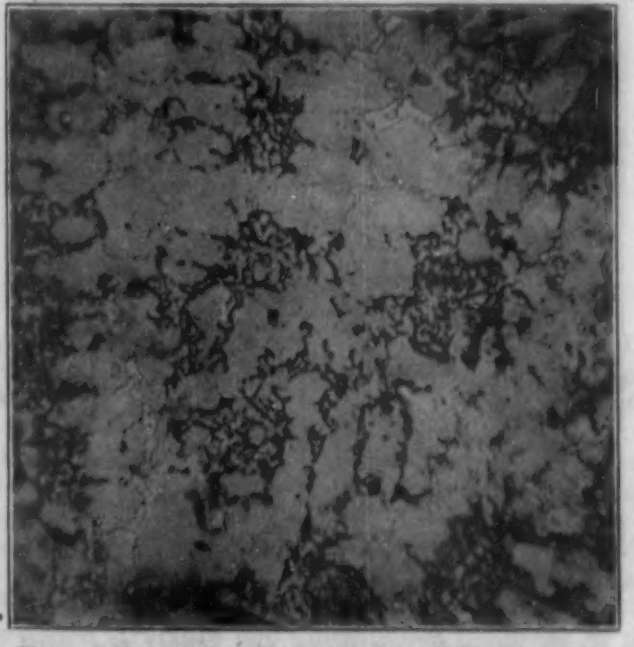

Fig. 14. The same as Fig. 12, but at 430X. The white areas are probably the phosphide eutectic, but do not display the typical dotted structure. 430X.

Fig. 15. A view along the line of the weld. The weld metal, below the middle half, is the same as in Fig. 6. 100X.

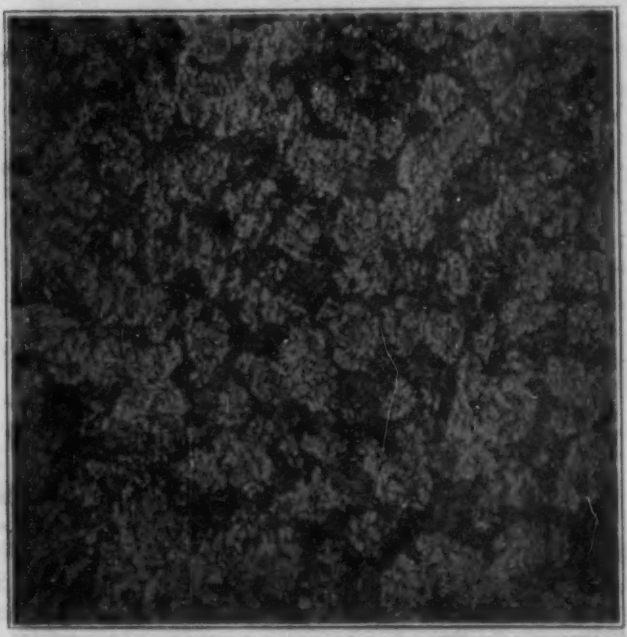

Fig. 16. Average view in the heat affected base metal showing the type of heat effect. The pearlite has assumed a network arrangement. Etched. 100X.

weld, the weld metal should be likewise stronger than the base metal. These deductions are sustained by actual results, as a piece of welded cast iron, if welded thoroughly, invariably breaks at some distance from the weld.

Cast Iron Welding of Centrifugal Cast Iron Pipe:

Fig. 11 is a section through this type of weld. This has the same general appearance as the previous weld, the slight differences being due to the differences in the base metals. From the photomicrographs it will be seen that the base metal is highly dendritic. The graphite exists as minute flakes and there is practically no

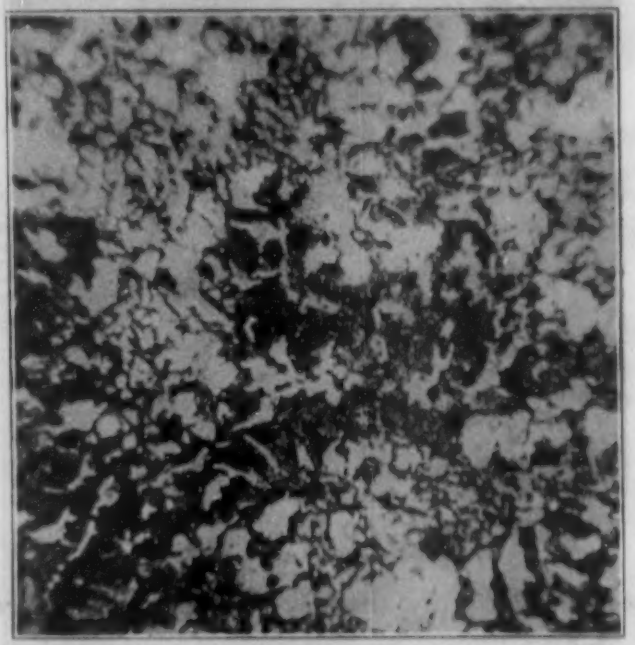

Fig. 17. A view in the pearlite bands near the extreme right end of the heat effect as shown in Fig. 11. The pearlite follows the phosphide eutectic shown in Fig. 14 which does not have the dotted structure. 430X.

pearlite, indicating that there is little combined carbon. Likewise, there is practically no phosphide eutectic of the type found in the sand cast iron pipes. Instead there is the white constituent shown in Fig. 14 with the graphite and ferrite. As this constituent is traced through the heat affected parts of the pipe, compare Figs. 17 and 18, it will be noticed that it always accompanies the pearlite network and gradually assumes the typical phosphide eutectic structure. From this it seems logical to deduce that the white constituent is the eutectic of iron carbide, iron phosphide, and iron, which, due to the rapid cooling of the pipe when made, did not develop its dotted structure but which, when tempered by the welding heat, gradually gave up part of its cementite to form pearlite

and also assumed its eutectic structure. This seems to be the best way to explain the results obtained.

The heat effect consists of the formation of a network of pearlite surrounding the previous groups of graphite plates. The weld metal is the same as in the previous case. Also, there was no determinable increase in the number or size of the graphite plates

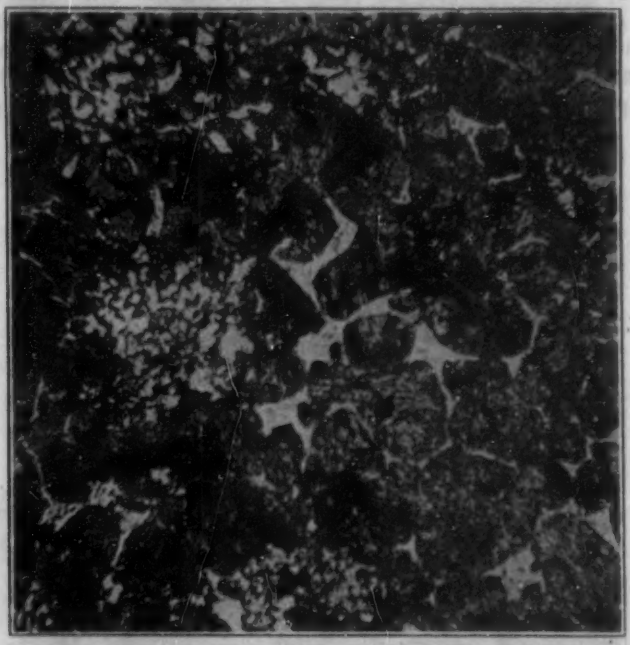

Fig. 18. A view in the pearlite bands near the weld metal. Here the phosphide has attained its dotted appearance due to the tempering effect of the heat. 430X.

in any section. As before, the only changes tend to increase the strength of the pipe.

Bronze Welding of Centrifugal Cast Iron Pipe:

Fig. 19 is a section through this type of weld. The heat effect in this case is limited to the darkened arc under the bronze.

The structure of the base metal is, of course, about the same as described above. The difference is that in this piece there are flakes of graphite resembling those of sand cast iron.

The structural change due to the heat consists only of a solution of the cementite as before and its precipitation as sorbite. The difference between the heat effect in this case and in the cast iron welded specimens is probably due to the differing rates of heating and cooling as well as to the difference in maximum temperatures. Owing to the fineness of the resulting structure, it was difficult to detect the various constituents, but it is believed that if any unexpected changes occurred, they are so minute as to be of little con-

sequence. Inasmuch as no such changes were found after cast iron welding, it is hardly probable that bronze welding could produce any further change as bronze welding takes place at a much lower temperature.

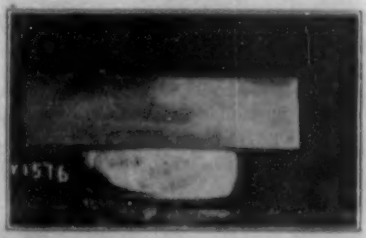

Fig. 19. Full size etched section through a bronze weld in centrifugal cast pipe. The heat effect is included within the darkened arc under the bronze.

Fig. 20. Average view of the centrifugal cast pipe unetched. This specimen differed from any of the others of the same type in the large flakes present. 100X.

Bronze Welding of Sand Cast Pipe:

Fig. 22 is a section through this type of weld and shows the extent of the heat affected base metal. This is included in the darkened arc under the bronze.

The structural change again consists of the formation of a sor-

bitic area in which no increased amount of graphite was noticed.

Due to the general large size of the constituents of the sand cast pipe, several things were noted that were not observed in the centrifugal cast pipes. The first is that the bronze often penetrates the cast iron to a distance of about 1/20 in. and appears in masses in the cast iron. These masses always assume the same shape and position as the phosphide eutectic areas and, as in Figs. 26 and 27,

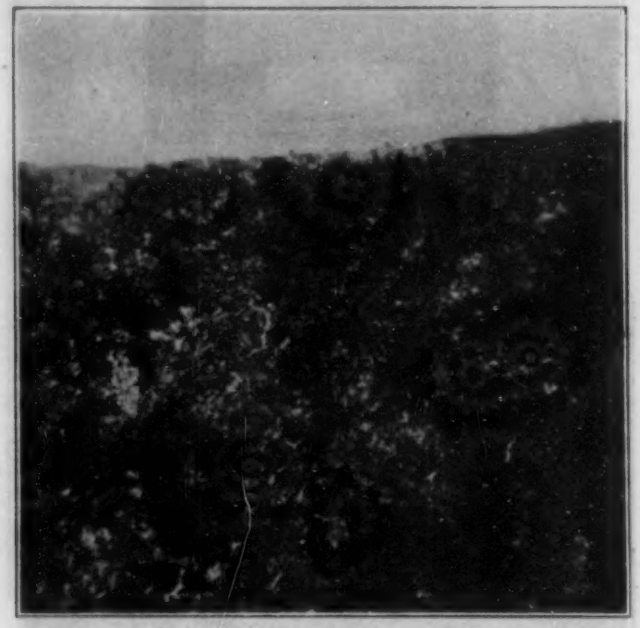

Fig. 31. Average view of the change in the base metal due to the heat. The structure is sorbitic. The bronze is shown above the cast iron. 430X.

seem to displace it or alloy with it as the color is yellow, like the bronze.

In one of the specimens examined, the crack shown in Fig. 28 was found. This crack is filled with iron oxide and the adjacent material has been almost entirely decarburized. In the bronze there is a blowhole formed, undoubtedly by the gases given off from the crack while hot. This crack, if in a pipe that was in service, might initiate failure unless the bronze was of sufficient strength to prevent this. It is possible that such cracks may be the cause for some of the failures that have occurred.

Several specimens of bronze welded sand cast iron pipes that failed in service were obtained and they were examined for any features that might explain their failure.

In one, a large number of areas such as in Fig. 30 was found just beneath the bronze. These represent either oxide or flux that has penetrated the cast iron. We were unable to connect this pene-

tration with any special constituent, but by bending the polished specimen under the microscope, it was shown that failure took place through these inclusions. Of course, they are too small to lead

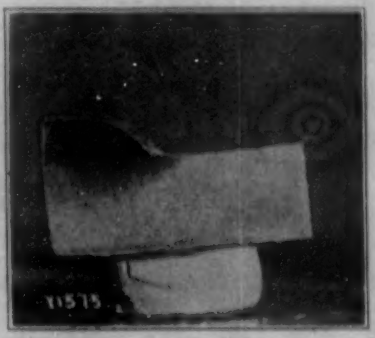

Fig. 22. Full size etched section through a bronze weld in sand cast pipe. The heat effect is included in the darkened arc under the bronze.

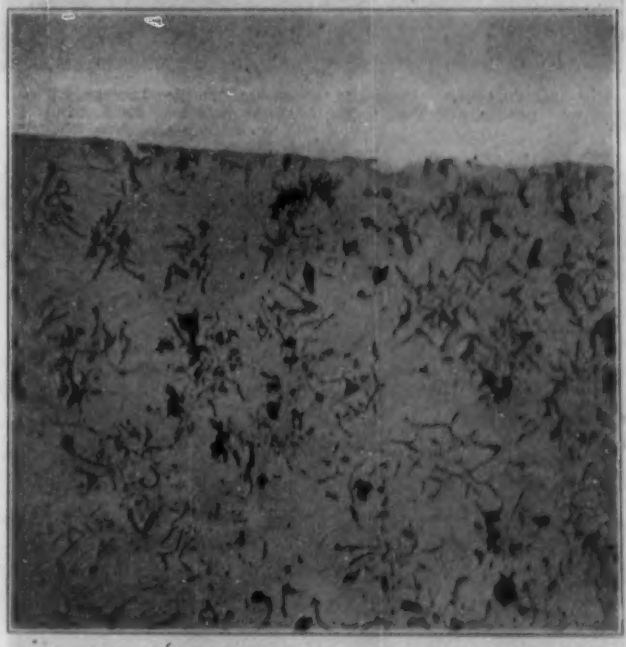

Fig. 23. Unetched view of the graphite under the bronze. A comparison with Fig. 3 shows that the graphite has not been changed. 100X.

in themselves to failure but they may play a part in causing it.

A specimen of French sand cast pipe that had failed was examined. This material is high in phosphorus, the specimen received analyzing 1.86 per cent of that element. From what has been said before, it might be deduced that the bronze penetrated the cast iron

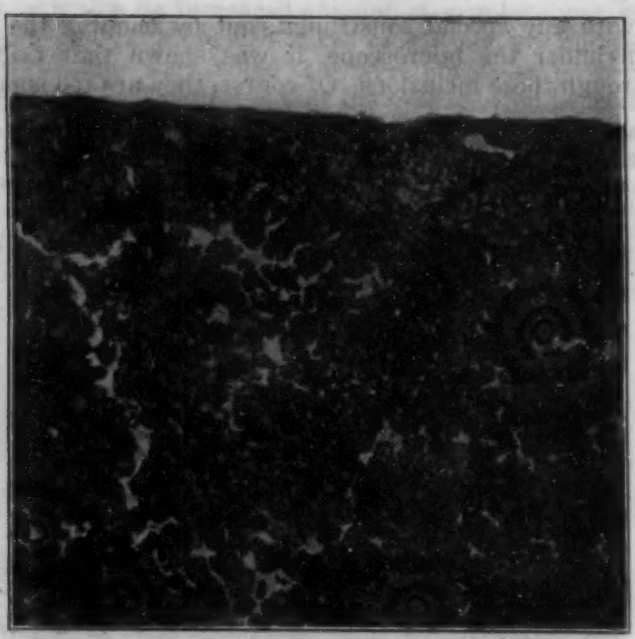

Fig. 24. Etched. Average view under the bronze. The pearlite of Fig. 4 has become sorbite. 100X.

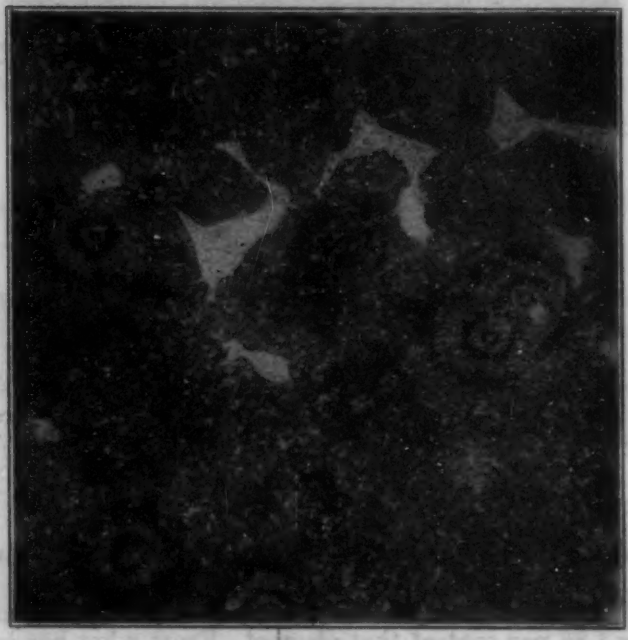

Fig. 25. View in the area shown in Fig. 24 showing the sorbitic structure. 430X.

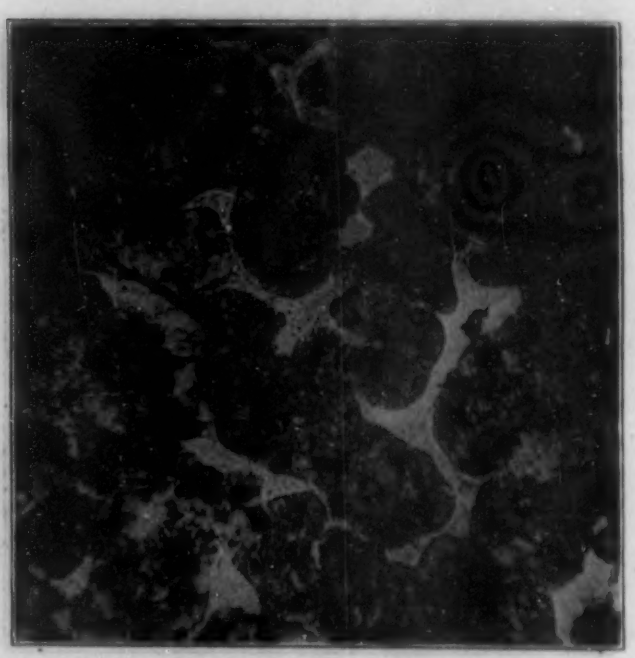

Fig. 26. Penetration of the cast iron by the bronze. The light area on the right is bronze colored, those on the left are phosphide eutectic as distinguished by their structure. 430X.

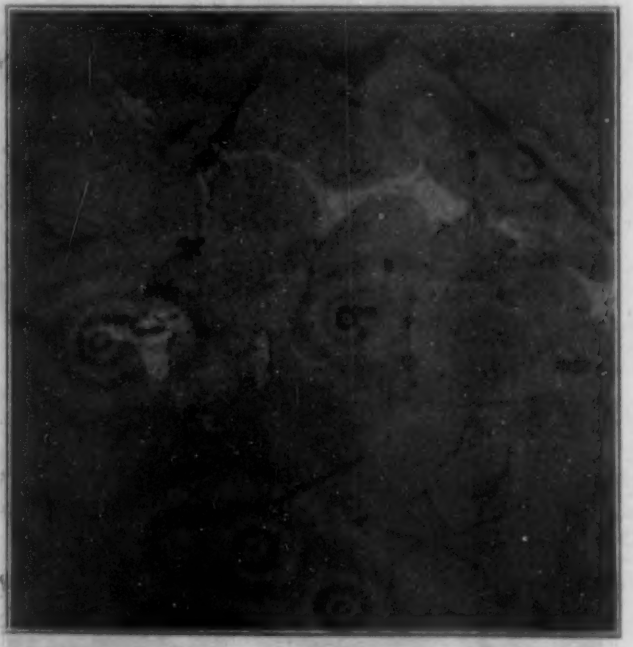

Fig. 27. Further evidence of the replacement of the phosphide eutectic by the bronze. The bronze is the light constituent in the design, the phosphide eutectic, the darker. 430X.

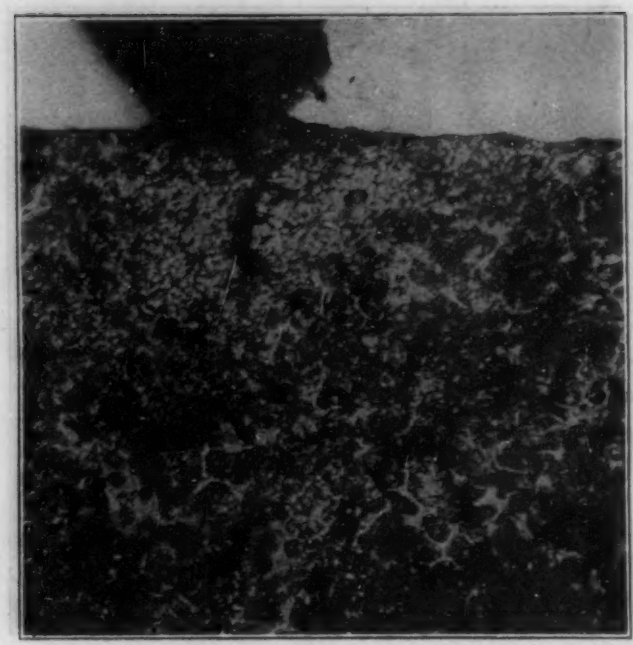

Fig. 28. A crack in the cast iron under the bronze. The iron has been decarburized in the vicinity and a blowhole has been formed as shown in the bronze above. 100X.

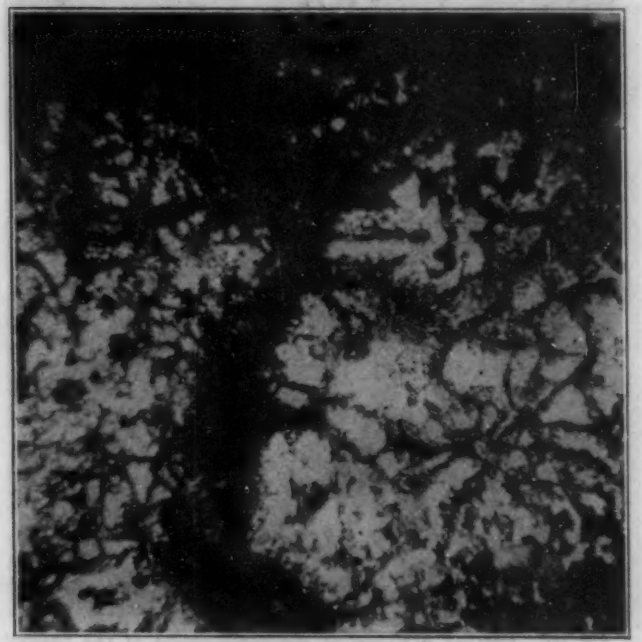

Fig. 29. This shows more clearly the crack and the apparently burnt material adjacent to it. 420X.

Fig. 30. One of the areas in which the flux or oxide has penetrated the cast iron. The welded surface is just below the edge of the picture. 430X.

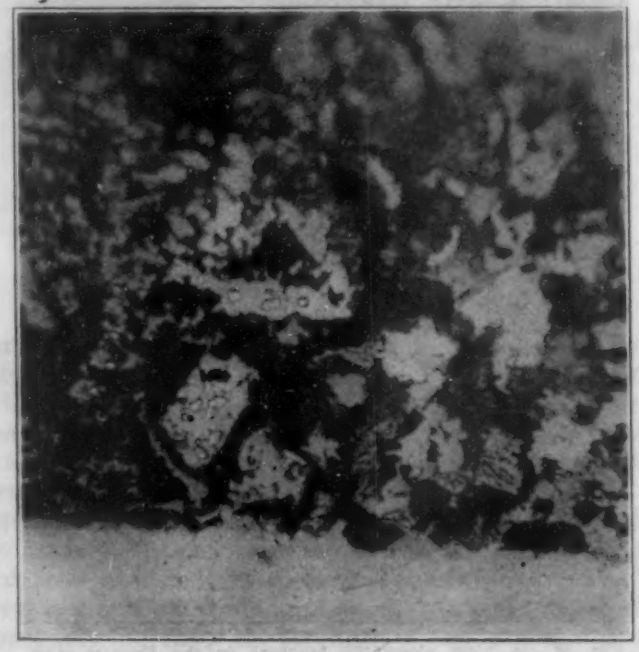

Fig. 31. Same specimen as Fig. 30, bent under the microscope. Fracture has taken place through the area shown in Fig. 30. 430X.

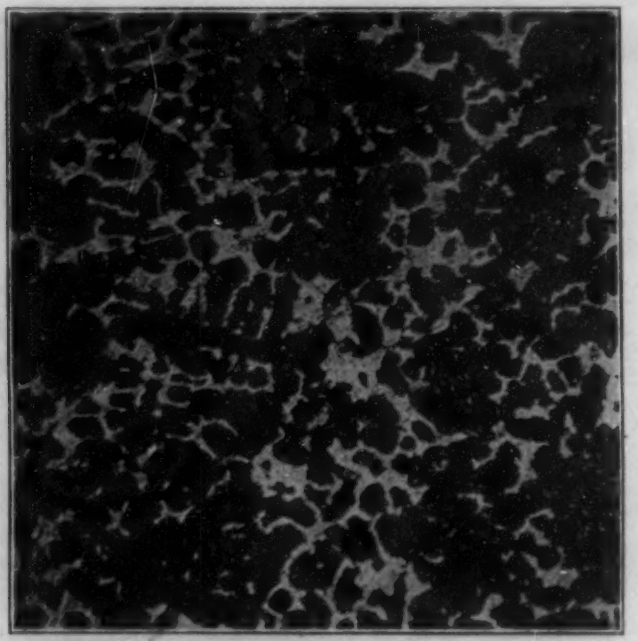

Fig. 32. Average view in the amount of phosphide eutectic in the French sand cast pipe. Compare with Fig. 4. 100X.

Fig. 33. A view along the fracture in the French sand cast pipe. The cast iron appears burnt and the bronze has penetrated quite completely as shown by the white areas. 430X.

quite thoroughly and that is true. All along the union, the phosphide had been more or less displaced by the bronze. An examination of the fracture itself proved that it took place through the cast iron adjacent to the bronze. Fig. 33 is a view along the fracture and Fig. 34 is at the end. The spongy discontinuous character of the metal is plainly evident. Fig. 35, which is somewhat similar to Fig. 28, was found just beyond the crack, but the condition of the metal is greatly similar to that at the fracture. From the shape of the porous areas they appear to be traces of the previous phosphide eutectic that has in some way been destroyed. In any case,

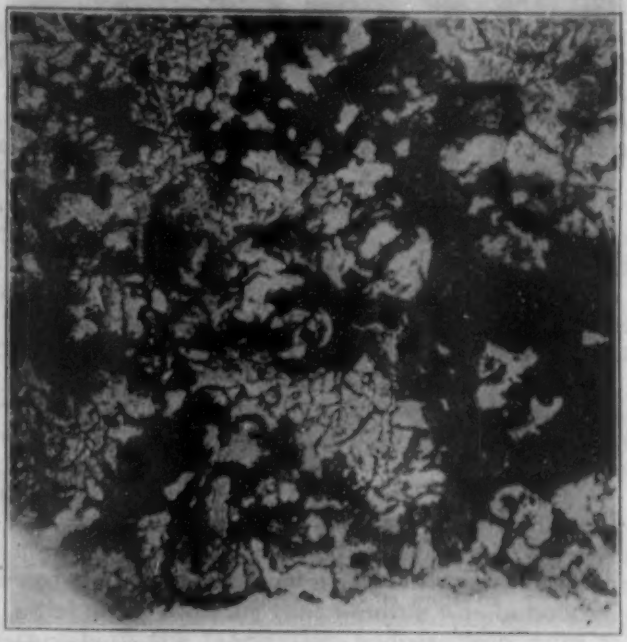

Fig. 34. A view at the end of the crack shown in Fig. 35. The cast iron is discontinuous and appears to have been burnt. 100X.

no matter what the reason for the failure may be, the only difference, besides the fact that the iron at the fracture has been decarburized, between the iron at and away from the fracture, is the absence or presence of the phosphide eutectic. It would seem that in the case of this type of pipe, the failure might be attributed to the presence of the unusual amount of phosphorus.

Of course, although the observation has been made that the bronze penetrates the cast iron, it must not be considered that the result is detrimental to the strength of the weld. Inasmuch as the bronze replaces the phosphide and perhaps some of the graphite, it more probably increases the strength of the iron as it is stronger than either of these constituents. It cannot be harmful to the properties of cast iron.

The reason for the fracture of the welds just outside the weld area seems to us more mechanical than the result of any structural change. If the end of the pipe had been made stronger or stiffer by means of an enlarged section there, it would be only natural that failure would take place, just at the base of such an enlarged section. The bronze collar or cast iron weld with the heat treated base metal is equivalent to such an increase in section and for the

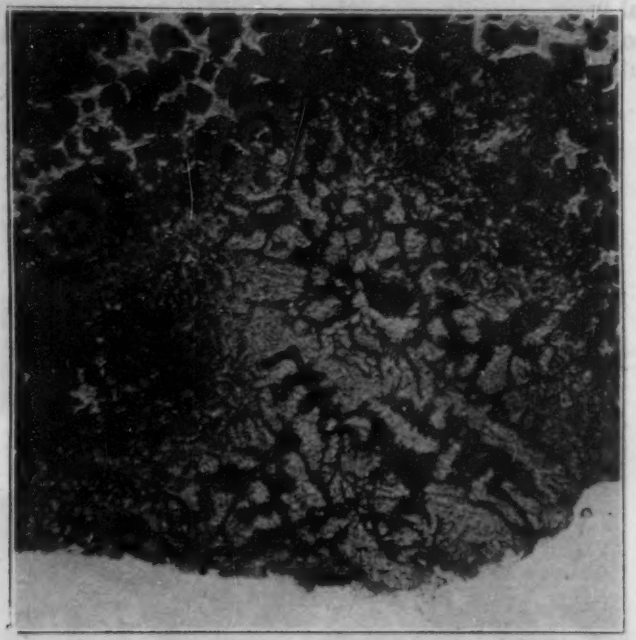

Fig. 35. A small defect found in the French sand cast pipe. It resembles the crack shown in Fig. 28. Note that the shape of the so-called burnt structure resembles the structure of the phosphide. 100X.

same reason causes the failure to occur in a corresponding location.

After a consideration of all the changes that have been observed to occur in cast iron pipe when welded with cast iron and bronze, we believe the following to be true.

1. Neither cast iron nor bronze welding of the usual cast iron pipe has any detrimental effect on the structure of the base metal.
2. It is possible that in cast iron very high in phosphorus, the bronze welding operation may weaken the material sufficiently to lead to failure though this is doubtful.
3. Inasmuch as both cast iron and bronze welding make the material at that point stronger, it is natural that many of the failures should occur just outside these altered areas.
4. It may well be that some of the failures that have occurred have been the result of surface cracks or defects in the original metal. The influence of these defects may be emphasized by the welding operation.

Structural Steel Welding on a Commercial Basis*

H. P. EGAN†

Completion of the new $75,000 two-story and basement commercial building for the Peerless Automobile Sales Company, in the heart of the business section of Canton, Ohio, marks the definite acceptance of electric arc welding as the coming process for joining members in the fabrication and erection of structural steel.

For the first time a company engaged in the erection of steel buildings on its own initiative put in a bid to fabricate a steel structure entirely by arc welding. The welding industry cannot give too much credit to the Morgan Engineering Company of Alliance, Ohio, and to Mr. R. A. Storms, the manager of its structural department, for this important step in the field of welding.

This job, insofar as the 95 tons of structural steel are concerned, is entirely welded, both in shop fabrication and erection. Not a single rivet has been used to join the various members which go to make up the steel framework of the heavy-duty building, 100 by 150 feet.

The Peerless Automobile Sales Company Building once and for all times takes the use of electric arc welding on structural jobs out of the laboratory and experimental class and puts the process on a production basis, in much the same manner as it has been accepted on a wide diversity of other lines where the joining of metal is involved. The Canton building, it should be remembered, is the first one of the sort in which welding in place of riveting was specified on a purely commercially sold job.

Although originally designed for rivets, the structural work was awarded the Morgan Engineering Company on a competitive basis, with the understanding that welding was to be used throughout, and that both the fabrication and erection were to be handled by the firm's structural department.

It should be remembered that on this undertaking only one of the bids received specified welding, and that the work went to the company making that one bid, in spite of the original plans calling for a riveted job.

The job was awarded, not with any special expectation of "cutting costs" on the part of the owners, but simply with the idea that a more satisfactory structure would result than would be possible were rivets used. Welding accomplished the ends desired by providing a factor of safety of eight, as against the usual four, resulting in stronger joints. Also a clean-cut job was made, completed on schedule time, and in addition important savings were made.

Before going into the detailed work involved in the fabrica-

*Presented at November, 1925, meeting, New York Section, A. W. S.
†Lincoln Electric Co.

tion and erection of the steel for this major commercial structure, it is well to get in mind some of the background which prompted the Morgan Engineering Company to recommend welding, even though the original drawings specified riveting. Up until the award of this job, their structural shops had followed the habitual procedure of riveting for such jobs, in much the manner pursued by other fabricators.

The Morgan Engineering Company determined to satisfy itself in every respect of the superiority of welded structural steel before it went into the competitive market and recommended its use on major buildings in preference to rivets. Over a period of years welding has been used extensively in its shops on locomotive repair and in production work on such things as gear cases. While it had

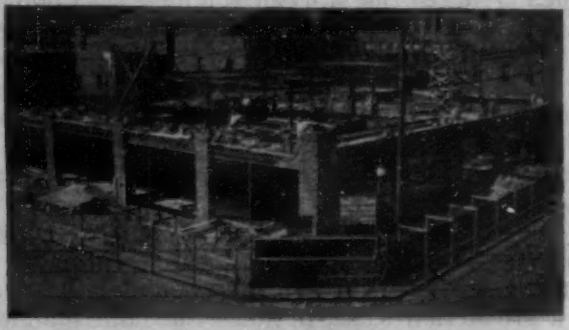

Fig. 1—General View of Building During Construction

proved itself in these fields beyond a question of doubt, still it was thought best to be absolutely certain of welding merits in structural work before definitely recommending it.

Not only were the extensive tests carefully studied, but all other available information on the use of electric arc welding in the different fields in which the problems were at all similar were also carefully studied.

Using conditions identical to those under which work would be carried forward in the ordinary run of structural steel fabrication in the shop, they subjected different types of welded and riveted joints to identical tests. In every instance it was found that the welded members held up in much superior fashion than did the riveted product.

In these tests there was no attempt to provide an especially good weld, built for laboratory purposes. Instead samples were used from welds made in the ordinary run of shop work, by all the different operators who would be engaged on structural steel fabrication, should the process be adopted as a standard practice.

A number of sample pieces were welded up and tested to destruction. The object of the samples was to discover how long and how wide a section of deposited metal would be required to equal the strengths of the different size rivets. For example, a

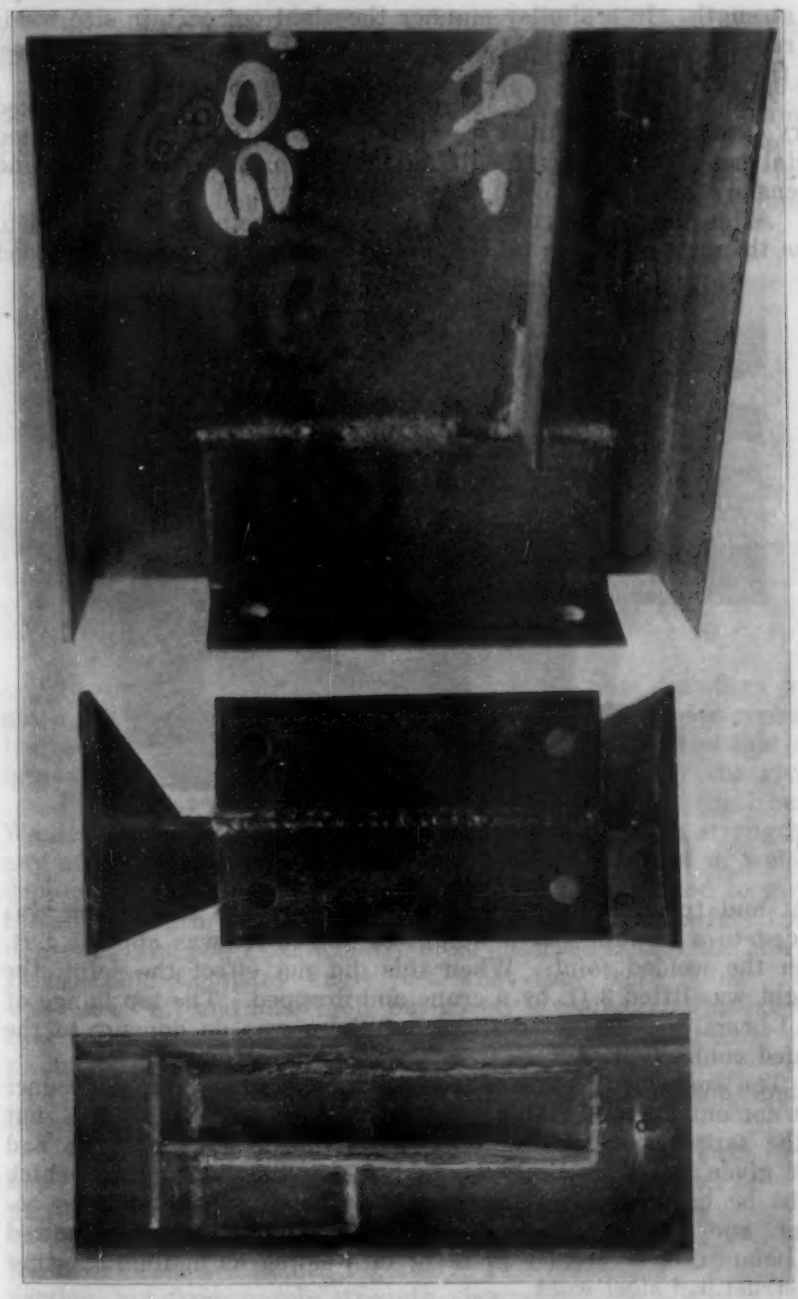

Fig. 1

Fig. 2

Fig. 3

¾ in. rivet has a strength of 22,000 lb. It was found that a weld 2 in. long and ⅜ in. wide had an average strength of 26,000 lb. On the job at Canton a 3 in. bead, ⅜ in. wide, was used instead of every ¾ in. rivet—this, you see, provided a 50 per cent increase

in strength. In a similar manner they laid out certain size welds to replace all the different size rivets which would have been used on the job.

The tests which the Morgan Engineering Co. made checked very closely with the tests we made. It was found that deposited metal has a shearing strength of 36,000 lb. per square inch and a tensile strength of 45,000 lb. per square inch.

After they had determined how much metal was required to give them the strength they required, they made a sample welded

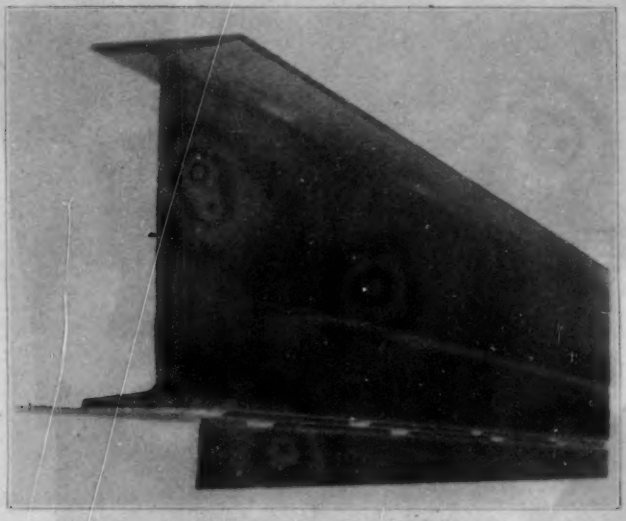

Fig. 5—Tack Welding Plates to Flanges

joint and tried to test it to destruction. An 8 in. I-beam was welded to a column and a weight of 19,700 lb. was applied 4 ft. from the welded joint. When this did not effect the joint, the weight was lifted 3 ft. by a crane and dropped. The top flange of the I-beam buckled out of line, but there was no damage to the welded connection.

The superiority of the welded joint over the riveted product was not only proved completely to the engineers of the firm, but to the satisfaction of a number of outside authorities, who had been given an opportunity to analyze results. Objections which might be brought from any possible source were taken into account, and still the investigations and tests of Morgan showed the balance sheet greatly in favor of welding as against riveting for structural steel work.

Fig. 1 gives a general view of the building during construction. The building is to be used as an automobile sales, service and storage plant and is of the wall bearing type, with a frontage of 150 ft. on one street and 100 ft. on another street. In addition

to full basement and two floors, the plans provide for an automobile run.

Specifications of the architects called for a live load of 60 lb. per square foot and a dead load of 30 lb. per square foot. Columns 8 in. H and 6 in. H were provided, with 18 in. and 12 in. I beams. There were fifteen column supports for the basement and each of the two main floors. On each column four beams were joined, each one designed to carry a total load of 58,000 lb.

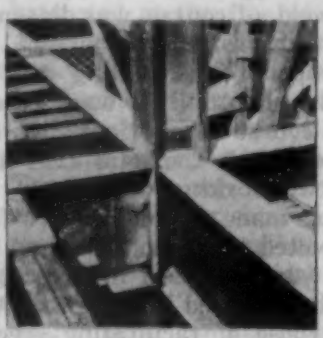

Fig. 6

Fig. 7

In order that work might be facilitated, new drawings were not made when it was decided to substitute welding for riveting. Instead it was simply specified on the original drawings that certain amounts of welding were to be substituted for the rivets.

Fig. 2 shows the shelf angle welded to the web of the I beam. We do not have the figures which show the estimated strength of any of the welded connections. However, the amount of welding done on every piece of steel in this job was estimated to give a certain strength, this strength arrived at by using a safety factor of eight. The point particularly to be observed is that the Morgan Engineering Company knew just what they were doing. This was not a "hit and miss" job, but purely a commercial proposition exactly the same as if the building had been constructed with rivets.

Figs. 3 and 4 show two views of how the connection angle is fastened on to the web of the floor beam.

Fig. 3 shows the tack welding used around the edge of the angle. This angle is one of the pieces of steel that can be eliminated or changed for a building designed for welded construction.

Fig. 4 shows how the angles on either side of the web of the floor beam are welded together. This makes a very solid connection, but from purely strength viewpoint most of the metal of the steel angle is wasted.

Fig. 5 shows the tack welding used to fasten the plates to the flanges of the beams. These plates carry walls and angles for windows.

All welding shown so far was done in the shop of the Morgan Engineering Co. Three men, operating arc welders of the portable type, did all of the welding necessary in the fabrication of structural steel. A total of 14,694 linear inches went into this portion of the work, and was completed in less than 80 per cent of the time which would have been required for the fabrication of the same 95 tons of steel had rivets been used.

The total number of welds made at the plant was 4171 of the following lengths: 14 in., 11½ in., 8½ in., 6 in., 5¾ in., 4 in., 3 in. and 2½ in. The length of the weld, of course, was determined by the duty which it was expected to perform.

While by far the greatest portion of the welding was done with the three welding outfits in the shop, still it was necessary to make 780 welds on the job in the course of erection. One operator, working with a portable welder, made the total 4294 inches of welding on the job in less than two working weeks.

Fig. 6 shows a completed joint as made on the job. To facilitate welding, the floor beams were bolted to the columns and shelf angle with two bolts. These bolts were not used in figuring the strength of the joint, and were simply anchored in place with welding after they had served their purpose of facilitating erection.

In spite of the fact that the building was not designed especially for arc welding, it was only necessary to do a very small per cent of overhead welding in erection. This per cent could have been further reduced had the original plans been drawn to provide for this process of joining.

It is well to remember that in calculating the amount of welding required for any joint, a safety factor of eight was used instead of the usual four, common in riveted construction.

However, in spite of the excess metal deposited, and in spite of the fact that the design was for riveting instead of welding, a saving of 23 per cent was made in shop fabrication costs, and all welding on the job was handled by one operator.

Had this building been designed for welded instead of riveted construction, a considerable additional saving could have been affected. Bars could have been used instead of angles for beam sets and plates welded to webs of beams at the ends instead of steel connection angles. Another recommendation would be to mill the floor beams to size, butt them against the columns and weld. A shelf bar would have to be used in this case, and the beam tacked in position as soon as placed by crane.

The ease with which the erection was done on the job created considerable comment, and the architects, Charles E. Firestone and Lowell Christman, and the general contractor, R. G. Whittens, all reported that considerable saving was affected on the balance of the construction work.

This, they state, is due to the fact that there was no interference to the work of other trades engaged on the construction such

as there would have been had riveting gangs of four each been used.

This brings us to the stumbling block which has prevented the adoption of arc welding for structural work before this—inspection of the welded joint.

The statement that a riveted joint can be inspected and a welded joint cannot is contrary to the facts.

Anyone familiar with welding knows that it is easy to tell a good weld from a poor one by looking at it. In addition, the weld can be tested at the line of fusion for penetration with a chisel and hammer. Any welds that will pass these two tests will average very close to the ultimate strength of deposited metal.

In comparison to the visual and hammer tests of a riveted joint, the inspection tests of an arc welded joint is the better because all the material to be inspected is in sight.

The constant inspection of welds both in the shop and on erection for the building showed beyond a doubt that constantly perfect welds are now possible. Thus there no longer need be any question as to the practicability of welding in structural work, from this angle.

The general contractors for this building, in commenting on this phase of the use of welding in place of riveting, point out that all that is required is the same sort of careful inspection as would be expected on a riveted job.

The fact that with good apparatus, design, technique, materials and supervision uniformly good welds can always be produced, when handled by competent operators, eliminates all objections to the use of welding. Add to this the facts which have been established in reference to relative strength of welded and riveted structural steel joints, and it becomes evident that, from the standpoint of safety, the newer method is far superior. In welding you come as near as is humanly possible to dealing with a known equation, while in riveting you are certain of having some unknown factor with each rivet driven.

This is an excellent recommendation for the operators and the management of the structural department. At regular intervals samples of every operator's work, picked at random, is tested to destruction. With this system, it has been found that in all cases the quality of an operator's work gradually increases. It is strongly recommended that all firms engaged in structural work be compelled to use some kind of similar system of testing their operator's work.

Another advantage to which attention has been called by the owners and architects, on the all-welded structure at Canton, is in connection with the comparative noise made by welding and riveting. One welder, operating entirely alone and without any noise, did all of the work. Had rivets been used, there would have been a gang of from four to six men at least, and the constant rap of the pneumatic hammer would have been a constant source

of annoyance to neighboring property and other tradesmen engaged on the building.

The management of one of the prominent hotels in New York City has stated through the newspapers that the noise of riveting of a building being erected near them will cause a loss of over a million dollars in loss of patronage before the building is completed.

Considering all of the factors which enter into the choice of a riveted as against a welded structure, so well pleased have been both the architects and the general contractors, that both have expressed their intention of using the welding process on other jobs in the future. They see the possibility that in the future welding will be considered the practical thing for all structural work.

Aside from the fact that welding was used in place of riveting on this commercially sold building, there has been nothing especially different about it than from other structures of like size and usage. Finished with face brick, it has Truscon steel roof and deck, with Carry roofing. Joists are the Berloy metal, and floors are concrete and tile over metal lumber.

Yet there can be no doubt but that the Peerless Auto Sales building will be marked down as embodying the first important major development in construction which has taken place for some years. Back of this step forward has been a splendid picture of cooperation, making it possible. Owners, architects and general contractors have all worked to cooperate with fabricators to make it a success.

Summing up the known facts which have become apparent as a result of this welded steel structure. In the first place as to the cost—it was found that a material reduction over the riveting cost was made possible in the shop fabrication by the use of welding. It is probable that in the future this saving can be still further increased.

In erection the welder in no way interfered with other operations, and money was saved to the general contractor on his other trades, according to his own statement.

Throughout the job it was shown that it is possible to secure a uniformly perfect job and one which lends itself to proper inspection, only requirements being the same sort of technical judgment needed in determining strengths as would be employed on a riveted job.

For the protection of arc welding in general, the following recommendations are made for any company that intends to enter the structural welding field:

First, only conscientious operators who take pride in their work be used.

Second, periodical destruction tests be made of the work of all operators.

Third, reliable welding machines and good wire be used.

Fourth, every welded joint be tested by competent inspectors.

Discussion, Fabricating Structural Steel with the "Electric Arc Process

R. A. STORM†

It will be necessary to take you back to some experiments made to enable us to increase the efficiency of our riveted connections in fabricating Electric Overhead Traveling Crane Girders.

The Morgan Engineering Company were the first ones to build cranes for handling hot metal in a Steel Mill. Were it not for such inventions as those of Thomas R. Morgan, Sr., the founder of our organization, it would be impossible to roll the plates and shapes necessary to fabricate a steel structure. There are no riveted connections, to my knowledge, where the rivets are subjected to more severe treatment than are the rivets in the girders of our open hearth charging machine cranes and our soaking pit charging cranes.

In order to make this paper more clear several illustrations have been prepared to show different uses of welding in this field.

Fig. No. 1. This slide shows rivets that were driven hot. You will note that it is physically impossible to make the rivet completely fill the hole. The shrinkage of the rivet precludes this. It is also impossible to heat the rivet and expose it to the air and prevent the oxidizing effect of the free oxygen of the air on the rivet. To overcome these conditions, we investigated the possibility of driving the rivets in our crane girders cold, using a cold pressed rivet to avoid a scale formation on the rivets purchased. Having heard that one concern drove rivets cold, up to and including 3 in. in diameter, I called on their Works Manager, to secure information regarding machines used to drive rivets and the methods used. He very kindly gave me all information requested. However, he stated that it was necessary to anneal rivets up to and including ¾ in. and, above that size, it was not necessary to anneal. I was very much interested to learn why it was necessary to anneal a ¾ in. rivet and not a ⅞ in. The Manager advised me that he could not explain why, although by experience he knew it was necessary to anneal up to and including ¾ in. in size. We then inquired of rivet machine manufacturers what style machines they built to perform this class of work, but we were unable to locate a desirable type to perform this operation, as it was necessary to use a portable machine. We then decided to ream our rivet holes only 1/32 in. over-size, instead of the customary 1/16 in., as we believe that this would provide a better riveting condition and all the holes in crane girders for shop driven rivets are reamed 1/32 in. over-size in our fabricating shop, and by this method, we find that we are able to increase the efficiency of our riveted connections in crane girders. It was necessary, however, that we use a

†Manager, Structural Engineering Department, Morgan Engineering Company.

cold pressed rivet, as they seem to be more uniform in size, and it is absolutely necessary that the rivets are not over-size, as a 3/4 in. rivet will expand almost 1/32 of an inch in heating.

During the War, I understood that the General Electric Company were building a heavy duty spot welder at their Schenectady Plant to weld plates up to and including 1 in. in thickness. I visited their plant at Schenectady, and, at that time, the machine was in the experimental state. Their difficulty was to provide electrodes to withstand the pressure required to bring the metal in contact which was necessary to perform the welding operation successfully.

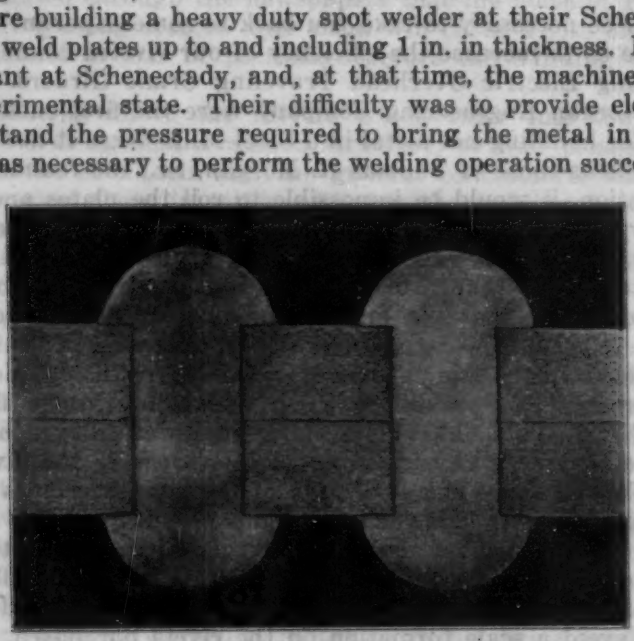

Fig. 1—Effect of Shrinkage of Rivets Driven Hot

I have been informed that they built one machine for heavy duty welding and shipped it to Hog Island Ship Yard. However, I have been unable to learn what service it gave.

During the years of 1922, 1923 and 1924, we completely rebuilt over 600 locomotives for ten different railroads. All of these were Class 1, 2 and 3 repairs. Class 3 repair means "necessary repairs to firebox and boiler and complete mechanical overhauling." Classes 1 and 2 repairs require "new boiler, new back end, or new fire box with complete mechanical overhauling." We found that all railroads that had contracts placed with us for this class of work permitted electric arc welding to be used in repairing the stayed part of the boilers. It was necessary for us to build up the large welding force to take care of our requirements in that line. We, of course, observed the efficiency of the electric arc welded joint in some of the sheet work in the fire boxes and noticed a number of cases where the electric arc weld had outlived the new sheets placed in the fireboxes when the locomotive had been overhauled. A great many fear the effects of impact and vibration on an electric weld. Quite a number of the railroads use this method successfully to repair broken locomotive frames. It is hard to conceive a more severe test on an electric weld than this one. This experience caused

us to experiment and make tests on the electric welded joint to replace, where expedient, the riveted joint in fabricating structural steel buildings.

Realizing the inefficiency of the riveted connections where the rivet is placed in tension, such as plates on the bottom of spandrel beams, we made several test pieces and submitted them to an overload and determined that the electric arc weld was far stronger than the calculated strength of a rivet in tension. In replacing the rivet used in tension, our next thought was to weld the shelf angles and connection angles. We again, conducted a series of tests, to

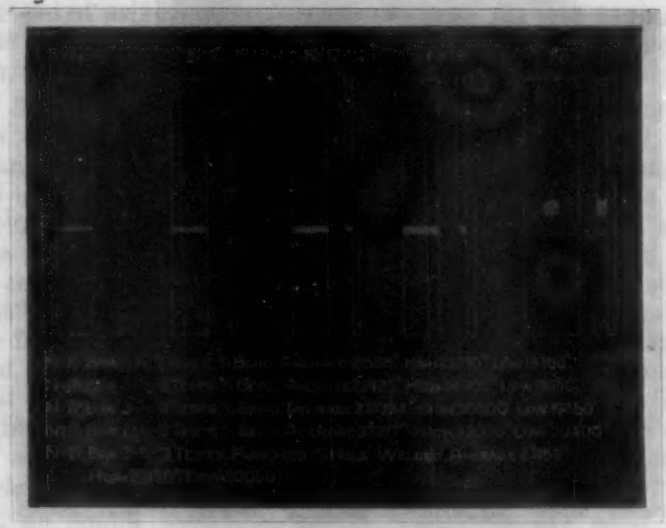

Fig. 2

determine the amount of weld required to compensate for the different sized rivets used.

Fig. 2 shows the results of these tests. I would like to call your attention to the fact that in all the tests we conducted, there was no attempt made to favor the weld. You will note from this figure that the welded joints in this series of tests were subjected to a severe bending moment. They were subject to an eccentric pull, and the specimens, having been lapped, would of necessity bend where lapped, when the force was applied. We compiled the following table from the result of these tests:

The equivalent strength in shear is as follows:

Rivet Dia.	Length ¼-in. Bead	Length 5/16-in. Bead	Length ⅜-in. Bead	Length ½-in. Bead
½ in.	1½ in.	1⅝ in.	1¼ in.	1⅛ in.
⅝ in.	2 in.	1⅞ in.	1⅝ in.	1⅛ in.
¾ in.	2⅝ in.	2⅛ in.	2¼ in.	1⅞ in.
⅞ in.	3⅜ in.	3¼ in.	2⅞ in.	2⅝ in.
1 in.	4¼ in.	4 in.	3½ in.	3 in.

One half inch added to theoretical length of weld, and rivet values figured at 10,000 lb. per square inch.

Having made a study of this art, and consulted a number of structural engineers, acquainting them with the results of our tests, we decided that we were justified in adopting this method to replace the riveted joint when expedient to do so. At this time, we

Upper Left, Fig. 3. Lower Left, Fig. 4. Right, Fig. 5.

learned of a building in Detroit that had several connections electric arc welded.

Having secured the contract for the fabricated structural steel to be used in the Peerless Auto Sales Company's Garage, located in Canton, O., we decided that we would attempt to sell all parties interested the idea of electric welding this steel frame, and we secured permission to completely electric weld the entire structure. Complete details of this building are given in Mr. Egan's paper.

Fig. 7. (Mr. Egan's paper) shows typical column connections on the roof. The columns were extended above the top of the beams and instead of using connecting angles where the roof beams frame into the web of the column, we welded the beams to the top of the column.

Fig. 3. (Mr. Egan's paper) shows method of welding angles on the end of the beam. The one angle was placed on the beam and welded to the web of the beam and the other angle was welded in place. We then had the third bead placed in this connection joining the first two beads. There are a number of ways to effect a saving in material and labor where a floor beam frames to the column. Where connecting angles are used, it is not so important that the beams be the exact length. Were we to substitute a plate for the angles, we could save material and the linear inches of weld, or, again, we can eliminate both the plate and the angles and cut beams to the exact length, and weld directly to column. With this type of construction it would necessitate the use of shelf angles welded on the columns with holes in horizontal leg of angles and holes to match in the bottom of the flange of beams.

You, no doubt, would be interested in knowing what savings could be effected with this method of fabrication. It would be presumptuous for me to attempt to state what savings all builders could effect, as the savings would depend upon your shop equipment and your individual ingenuity. On the building in Canton, we were able to save approximately 25 per cent in our estimated shop labor. This saving, can, no doubt, be increased eventually when quicker methods of assembling our materials are devised. When these beams were welded, we had three blocks of wood notched out to fit over the flange of the beams and the outstanding leg of the shelf angle. This obviated the work of a fitter for this operation. We then placed the beam on the top of the plate, and you can readily see that the services of a fitter were also unnecessary for this operation. Our shop was equipped primarily to build crane girders and miscellaneous structural parts for a crane, and it is possibly not as efficient on a straight beam and column fabricated job as most of your shops. If such is the case, we can effect a greater saving on this type of structure. It will no doubt be possible to reduce the size of some sections used in fabricating certain types of steel structures, as there will be no reduction or area in the welded joint. We decided to proceed with caution along this line,

as it is possible to become too enthusiastic and have our enthusiasm obfuscate our reason. On the building in Canton, there were 780 field welds, or 358 ft., an average of 5½ inches to the weld. One welder was 120 hours performing the work. We used 110 kilowatt hours for the field welding. When an operator is laying a continuous bead on straight work, he can average from 10 to 12 ft. per hour, with a ⅜ bead. The actual field welding time on this building was possibly 25 per cent of the total time. It is hardly possible, however, to use the linear feet welded per hour to estimate costs, as our costs will depend largely upon the type of joint, form of weld and the size of the bead. At the present time, we are fabricating the crane runway, and figures on the savings are not available at this time.

Fig. 3 shows method used to weld backs of angles to top and bottom edge of web plates. A continuous bead is used for a distance of 4 feet from each end and then intermittent tack welds are used.

Fig. 4 shows weld used on vertical leg of angle and web plates.

Fig. 5 shows method used to weld channel to top angles. You will note the savings of time in shop detailing, as it is not necessary to consider the interference of rivets. The girder was inverted when photographed, in order to show welds more clearly.

Fig. 6 shows the finished crane girder, with the exception of the stiffener angles. While it is not possible, at this time, to state the actual saving in shop labor in the fabrication of the girders, you can readily see how fabricating girders would be simplified by substituting electric arc welding for riveting.

One of the principal objections to this type of construction seems to be that there is no method of determining the efficiency of a welded joint without destruction. Is this not in a way true of the riveted joint? Does the hammer test conclusively prove that a rivet is not defective? We seriously doubt that it does. However, grant that it does. It is doubtful if more than 10 per cent of the rivets driven in fabricated structural steel buildings have been inspected. Would it be expedient for us to condemn the use of concrete for this same reason, as much as we might like to? I understand that at one time, several States had laws enacted, prohibiting its use in structures. When most of us think of a weld, there comes to our mind the uncertainties of a forge weld, or possibly we have had some of our automobile parts welded at the alley garage by an inefficient operator. A fusion weld is not nearly so indeterminate as the forge weld. A competent operator can always tell when he has an effectual weld. In considering the efficiency of a welded joint, the individual is a very important factor, and we should endeavor to maintain a very high standard among our operators. We exercise extreme care in the selection of our operators and test to destruction certain welds of each operator weekly. A very simple method of testing welds is to have test pieces made from two bars, bevel one end of each bar to 30 degrees, butt paral-

welded joint. We decided to proceed with caution along this line.

lel bevel end of bars and weld. Break these test pieces in the weld with a sledge or by bending in a "V" block in a press. An examination will then disclose the efficiency of the operator. It is well, however, to have standard test pieces made occasionally and pull in a standard tensile testing machine.

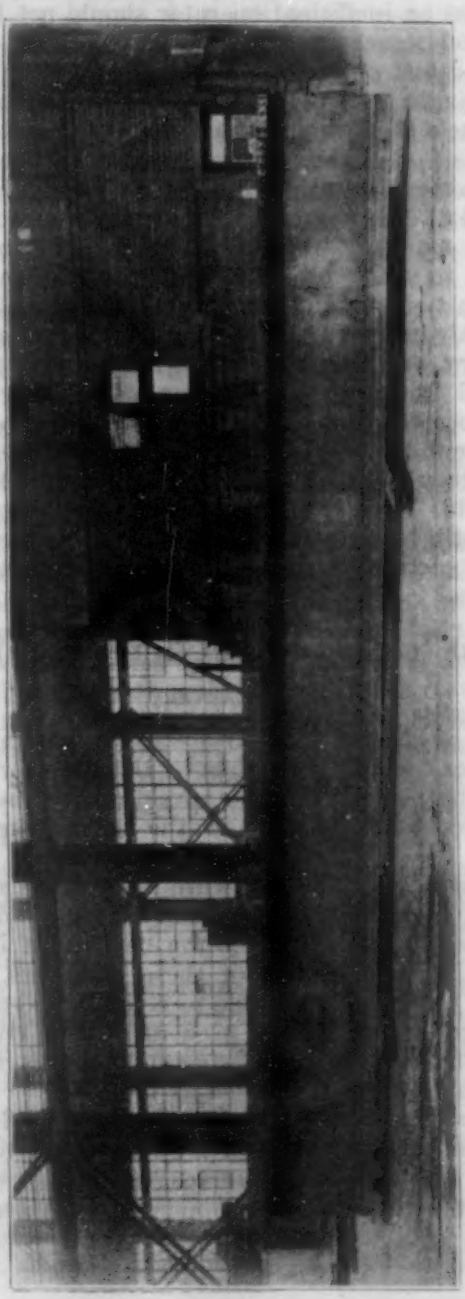

Fig. 6—Crane Girder

In order that the electric welding of steel structures will be guided along safe lines, structural engineers should give careful attention to the design, and use of a high factor of safety in the welded joint. Some method should be determined that will protect the purchaser, and a fabricator who has no knowledge of the art and possibly has an inefficient operator should not be permitted to fabricate a steel structure with this method until he can submit certain certified test specimens that test up to the required standards, as one single failure with this method of construction would create an obstacle that would retard our progress considerably.

Quite a few of us expressed the thought that electric arc welding is in the experimental state. This is hardly fair, as the art was discovered 35 years ago. However, the same conditions have prevailed with many desirable discoveries. The industrial world has been slow to make practical application of new inventions. Take the steam turbine, and consider the length of time required for Sir Chas. Algernon Parsons to have the commercial world utilize his discovery, and then were it not for Parsons' audacity at the Spithead Naval Review in 1897, when with his trim ship "Turbinia," he deliberately cut across the bow of the royal yacht and when the Commander of the fleet ordered his fastest picket boats to give chase, they were left far behind. Parsons had the fastest ship in the world. Were it not for this display of speed, the steam turbine might still be in the embryonic state like the art of electric welding steel structures in this country at the present time.

Design for Oxy-Acetylene Welding*

G. O. CARTER†

The subject of design for oxy-acetylene welding probably is understood better by the welder than by the engineer today. Many welders know that an excellent butt weld can be made, whereas a fillet weld is seldom satisfactory, yet the latter is generally shown on drawings.

Designing engineers familiar with riveted construction, who have not had the benefit of advice from a good welder or welding engineer, frequently fail to realize the bearing of design on successful welding. The tendency of these engineers is to call for designs such as would be applicable to riveting, except that a fillet weld at the edge of the plate is used instead of rivets. When a design that is not the most satisfactory reaches the welder he has no option to do other than weld as indicated.

The principles in design required to satisfy welding conditions are few and when once understood are easy to apply in any given case. The first major principle for oxy-acetylene welding is that butt joints are much preferred to lap joints. A second principle

*Presented Dec. 19 meeting, Pittsburgh Section, A. W. S.
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is that where a fillet weld is used it should be balanced up with other welds or fastenings so as to prevent bending action which we frequently term "peeling."

Wherever possible welds should be made from two sides if the work is of major importance. There are some places such as a circumferential weld of pipe where it is not possible to weld from both sides. On the other hand, the circumferential joint in pipe is only under half the stress that the longitudinal seam is under due to internal pressure. With proper expansion joints, well made circumferential pipe welds never fail. The provisions that are frequently made for fitting a sleeve over a circumferential pipe weld and lap welding same to the pipe are quite unnecessary in a properly designed installation. Even if the underlying butt weld is weak, this extra sleeve does not add appreciable strength to the joint.

From the above we may therefore state that circumferential welds in pipe may be properly made by welding from one side and that they do not require a covering sleeve or other reinforcement. In designs a butt welded line can be shown with straightaway parallel lines except where valves or bends are required. This speeds up pipe design work and reduces drafting expenses. Another advantage to the designer is that by having a tube of uniform diameter practically its whole length the problem of insulation becomes very simple.

Before leaving the subject of piping, it would be well to discuss the welding of bends, necks, wyes, etc., as it has frequently happened in the past that the layout of a joint was left to the welder. The proper laying out of a joint for either a short bend or a long bend is quite a problem for anyone but an experienced engineer or draftsman. It is surprising that welders and foremen have done as well in handling these problems as they have. In some big shops templates for laying out joints with various size pipe are kept at hand. Where such templates are not provided, it should be the duty of the engineer to provide a template for the welder to use in his lay-out.

In many installations 90 deg. bends are used, because designers have not laid out templates for shorter bends, which would enable the welders to make 2, 3 or 4 piece bends. The right angle bends, frequently called "stove pipe bends," cause such an abrupt change in direction of flow of gas or liquid that they are not efficient. Attention should be paid to this phase of pipe design.

In making 2, 3 or 4-piece bends the welds should not be crowded so close together that the heat from making one weld will affect the adjacent one. The nearest approach of one weld to another should be 4 in. and it is better to have the minimum distances two or three times that amount.

Templates should also be made up for laying out the hole in a header and for cutting the end of a branch pipe when neck welds are called for. Special instructions for this work can be obtained,

but the general principle of this lay out is to so prepare the abutting edges that the welding flame may reach to the bottom of both the header and branch.

On pipe installations where fittings require flange connections, forged flanges with at least a 6-in. skirt may be welded to the line. Where forged flanges cannot be obtained, plate steel may be cut in the form of a ring that will fit over the end of the pipe and a weld made between the end of the pipe and inside lip of the ring. A fillet weld should then be made on the back edge of the ring and the body of the pipe. This procedure will make a sound joint, but will almost always warp the ring enough to necessitate truing up.

A standard Van Stone all-forged steel flange with skirt or neck is preferable. However, if a Van Stone nipple is not available it is better to have a cast steel flange made with a skirt of from 3 to 6 in. in length. The end of the pipe and the face of this flange should be welded as with the plate ring. Then the end of the skirt should be welded to the pipe. By spreading the heat of the two welding operations from 4 to 6 in. distortion is largely avoided. It is well to reserve any finishing operations until the welds have been made. These flanged connections should be made with short lengths of pipe (6 in. to 3 ft.) and these may then be welded directly to the line with a butt or neck weld.

For closing the ends of pipe a very satisfactory weld is the "orange peel" type, although a tee joint type may be used. Reducers are provided for reduction in the size of pipe and may be made by slitting pipe longitudinally, heating the resulting sections and swaging them down to the new sizes. In any of these operations, the cutting torch is about the only feasible tool for doing the trimming and when the joint is ready for welding the adjacent edges should fit flush to one another, with just enough separation to get good penetration in welding. The "orange peel" plug gives 100 per cent strength, is free from difficulties experienced in making flat plugs or screw caps and is economical.

In other than pipe work, all important welds should be of the double butt type. This does not mean that both sides of the weld must always be of same depth, because the same strength weld may be expected when one side is two-thirds and the other one-third of the plate thickness.

The reason why double welding is to be preferred to single welding is that imperfections are most apt to occur at the bottom of a weld. In welding from one side the bottom of a weld is on the under side of the plate. Imperfections would therefore leave a groove, and it is well known that grooves and seams are objectionable. In double welding the defect at the bottom of one weld would be compensated for by the weld on the other side so that there would be no groove or imperfection at the surface of the plate. Any defect resulting from imperfect penetration would come at the center of the plate, where it would not grow under

alternating stresses. In any event, if the welds are properly reinforced on each side there will be ample strength at the joint.

Under tension or side ways reversal of stresses the properly made double weld gives almost perfect satisfaction.

Circumferential seams in structures that are big enough to enter should be double welded. In pressure tanks it is best to have the heads made in one piece and flanged with the skirt at least 3 in. in length. The heads should be applied with the convex surface outward and the end of the skirt should butt to the shell of a tank where double welding should be utilized. Slipping the head inside the shell, forging the end of the shell slightly over the shoulder of the head and welding the tank and head with a fillet weld does not give any greater strength than the butt weld just described.

Nipples larger than 6 in. in diameter for tanks should be forged so as to open out like the end of a horn to permit welding with a double weld flush with the shell of the tank. In all cases nipples should be welded both inside and outside as this gives strength and assures tightness.

It should be the province of a designing engineer to specify that welders who will work on a given job must pass certain qualification tests. The designer should also indicate the grade of materials to be used, such as fire-box or flange quality steel for important pressure vessels. A further material provision should be that the welding rod be of high grade material so as to permit the development of the full strength of plate. At present the permissible design stress for a joint is 8000 lb. per sq. in.

The designer should also specify a test for the finished work, and he should specify a test that will subject the joint to a stress up to the elastic limit of the material, approximately 25,000 lb. In pressure vessels a test three times the working pressure is therefore advisable. Where a tension test is being applied it is advantageous to apply a hammer test when the stress is double the working stress. The subsequent raising of the pressure to three times the working pressure will make sure that no hidden defects remain from the hammering.

As an interesting example of welding I will describe the construction of a special heat interchanger, recently built, having cast steel flanges and plate steel body. This welded construction proved very satisfactory under most severe conditions. Numerous other examples of design for welding could be given but, as it outlines some of the principal things to keep in mind, this one example should be sufficient to point the way for those designing engineers who want to know how to take advantage of oxy-acetylene welding in their work.

Considering the wonderful success of oxy-acetylene welding in important work and remembering that the fabricator will follow the drawings exactly, it is certainly up to designing engineers to study the problem of proper design for welded construction.

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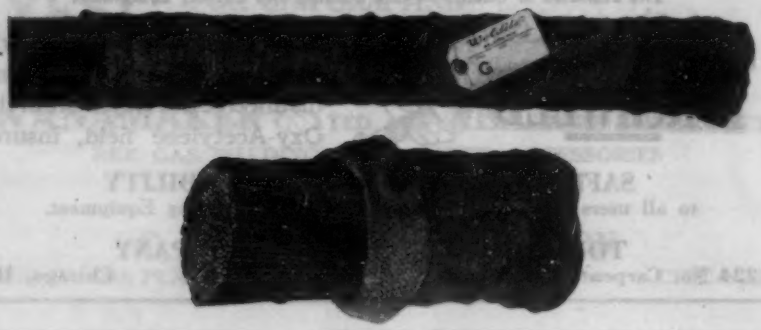

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"You know how it is. If there's any trouble with a weld—if it isn't right—why, the blame comes right back to us fellows who do the work. So you see, I don't want to take any chances. I want Wilson Wire. I *know* IT'S alright—it runs uniform all the way through. And that's true of every grade of Wilson Wire. You know Wilson has a grade for every kind of welding."

And he is right, why should he be blamed for poor welding when it's the fault of the wire? Good welders want to protect their reputations, so they want Wilson Wire. Why not give it to them? There is no economy in inferior wires. And among the different Wilson grades, there is just the right analysis of wire for every kind of metal you desire to weld. Simply tell Wilson or a Wilson distributor what class of welding you are doing. You can depend upon the uniformity and flowing quality of every grade (analysis) of Wilson Wire. Each is designated by color: Hence Wilson "Color-tipt" Welding Wire. Write today for prices and samples, indicating the kind of metal you desire to weld.

WILSON WELDER & METALS CO. INC., WILSON BLDG., HOBOKEN, NEW JERSEY

WILSON

WELDING MACHINES AND WELDING WIRE

Lift yourself by your boot straps

THROUGHOUT the past year these advertisements have told you about Linde Process Service for Linde users. They have shown how it can help you, whether you have only a comparatively simple job, or whether you want to make the oxy-acetylene process part of your production work with all the managerial and engineering problems that this involves.

Linde Process Service goes even further. Under the title of Procedure Control, instructions are being assembled for every application of the oxy-acetylene process. So, when you ask for help, we shall be able to send you a set of instructions for your particular job. They will tell you how to select your materials, how to instruct your welders, how to set up and carry out the work, and how to test the finished job.

So you can, in reality, lift yourself by your boot straps. Linde Service men will always be available when needed, but, with the aid of Procedure Control alone, you will be able to apply the oxy-acetylene process to your manufacturing problems.

Next year our advertising will describe some of the outstanding achievements of the oxy-acetylene process in industry—achievements made possible by the use of Linde Process Service.

Check the books you want, tear out this list and mail it to the nearest District Office

- ☐ Cast Iron Welding by the Oxy-Acetylene Process
- ☐ The Dependability of Cast Iron Welding
- ☐ Gas Welded Pipe Joints
- ☐ How Welded Joints Solved Pipe Line Troubles
- ☐ Step by Step in Oxwelding a Pipe Joint
- ☐ Welding Small Tanks by the Oxy-Acetylene Process
- ☐ The Oxygen Lance
- ☐ Welding and Cutting for the Manufacture and Maintenance of Chemical Equipment
- ☐ Step by Step in Gas Welding a Cylinder Block
- ☐ Severing Metals by Oxidation
- ☐ The Handling, Storage and Return of Cylinders for Compressed Gases
- ☐ The Importance of Managerial Understanding of Welding

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37 Plants *22 District Sales Offices* *91 Warehouses*

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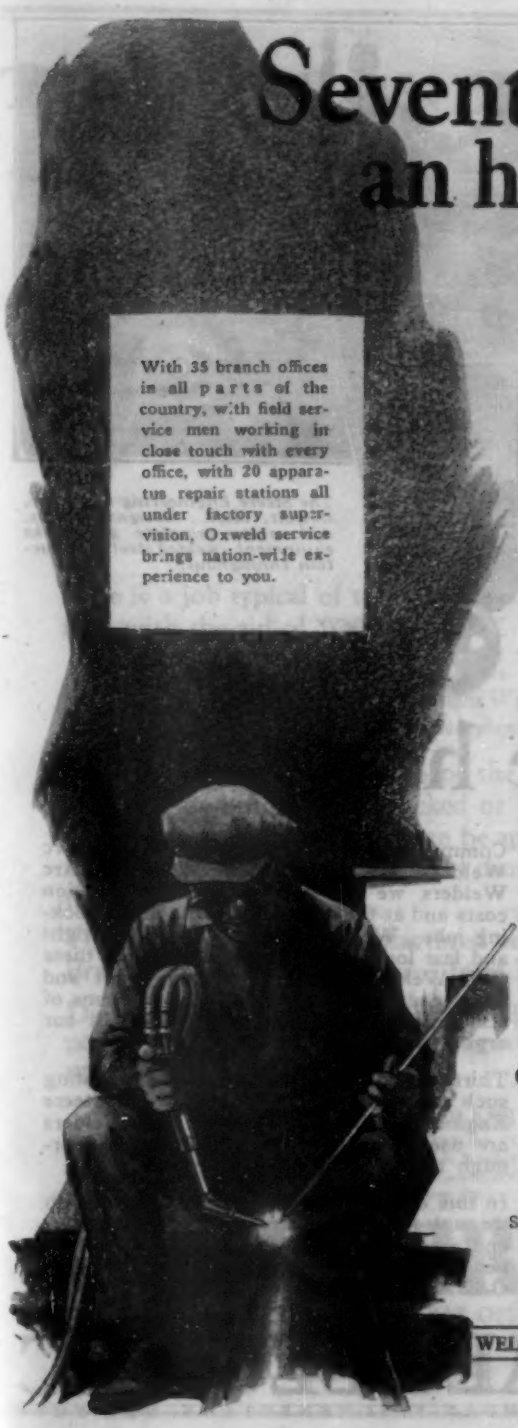
31 Plants—71 Warehouses—22 District Sales Offices

Seventy miles an hour—*plus*



With 35 branch offices in all parts of the country, with field service men working in close touch with every office, with 20 apparatus repair stations all under factory supervision, Oxweld service brings nation-wide experience to you.

Probably you would never want to go seventy miles an hour in your automobile. But it is a comfort to know that your car is built to stand this unusual strain. That's what the *plus* means.

The same thing is true of Oxweld equipment. Built for unusual service it will stand the wear of average industrial use without having to call on its reserve—the "plus," as it is so aptly called.

Oxweld *plus* also means service—real service. It is brought to you by a large force of practical field men. It enables you to utilize the oxy-acetylene process more widely and more efficiently.

OXWELD ACETYLENE COMPANY

LONG ISLAND CITY, N. Y.
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CHICAGO, 3642 Jasper Place

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Oxweld

WELDING AND CUTTING APPARATUS

The Steere Engineering Company, Detroit, Mich., designs, builds, and erects complete gas works equipment—welded steel construction throughout.

Steere has 36

Commenting on the service of G-E Arc Welders, Mr. Steere says, "With G-E Arc Welders we are able to cut construction costs and at the same time make better looking jobs. Welded joints are absolutely tight and last longer. The ease with which these G-E Welders could be moved about and their ready adaptability for various forms of service, also account for their favor in our organization."

Thirty-six G-E Arc Welders are fabricating such shapes as the one shown for the Steere Engineering Company. Only G-E Welders are used—the selection came after a thorough trial.

In this case arc welding makes a neater job through the elimination of joints and fittings, and a construction which is much more dependable. It is typical of the developments G-E Arc Welders make possible.

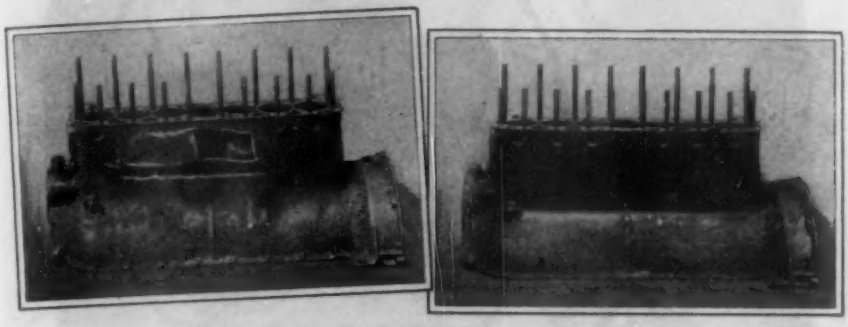
Wherever metals are to be joined, built up, or cut down, G-E Arc Welders will do the job most efficiently. For your convenience Arc Welding specialists are located in every G-E sales office.

28-120

GENERAL ELECTRIC

GENERAL ELECTRIC COMPANY, SCHENECTADY, NEW YORK

TOBIN BRONZE WELDED



This illustration shows the water jacket welded and painted—as good as new.

Here is a job typical of the class of work being done on cast iron with the aid of TOBIN BRONZE Welding Rods.

Actual time on job—three hours. Material used —one lb. of 1/8" Tobin Bronze Welding Rod and 60 cubic feet of Oxy-Acetylene Gas.

Tobin Bronze is conceded to be the best welding rod for repairing or building up cracked or broken cast iron parts of any size or description. It can be applied at a dull red heat without pre-heating, and the weld thus made is stronger than the original cast iron.

Tobin Bronze Rods, manufactured solely by The American Brass Company, can be secured from leading Distributors.

Descriptive pamphlet, including tables of weights, melting points, also suggestions for welding with Tobin Bronze, sent upon request.

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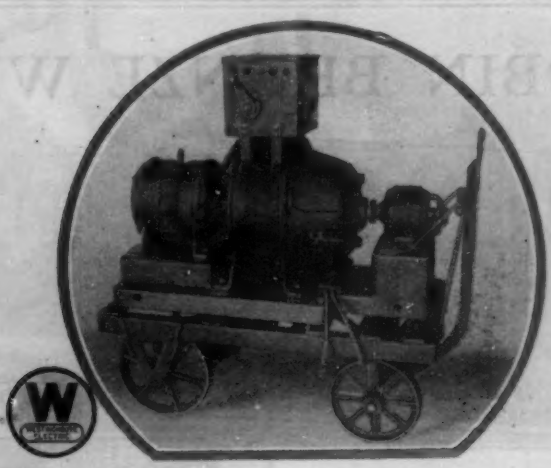
WELDING RODS



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CONSTANT current is the most vital essential to good welding—a distinctive characteristic of the Westinghouse 200 ampere Arc Welding Set.

The Westinghouse Portable Arc Welder is so designed that for a considerable change in the arc voltage, due to changing the arc length, there will be only a small change in the current.

This constant current characteristic maintains a constant temperature at the surface of the electrode tip. Good fusion and a solid weld is the result.

Assure yourself of this superior operating advantage. Specify Westinghouse Arc Welding Sets.

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for perfect work on every type of welding

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This means perfect welding—no time and money lost because of inferior material causing spoiled or unsatisfactory results.

Page supplies the correct grade of wire and electrode for *any* job—Page Mild Steel Gas Welding Wire and Electrodes, Page-Armco Wire and Electrodes and Page High Carbon Wire and Electrodes will enable you to make the most out of your welders' time and skill.

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PAGE-ARMCO PROCESSED

Welding Wire *and* Electrodes

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The Lincoln "Stable-Arc" Welder is designed to furnish *instantly* a change in voltage to take care of any extraordinary demand of the arc.

This is due to the fact that the frame, as well as the fields of the generator, is constructed of laminated steel which decreases the reluctance of the magnetic circuit.

The result is "Stable-Arc"—the easiest arc to maintain. The inevitable result is faster and better work.

Operators prefer Lincoln "Stable-Arc" Welders for this reason.

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"Stable-Arc"
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Welding
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conforms to the specifications of the American Welding Society. Exacting tests have proven that it possesses those qualities essential to good welding.

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speed and economy in joining metals, but also the necessary strength, toughness and resistance to impact of the weld metal.

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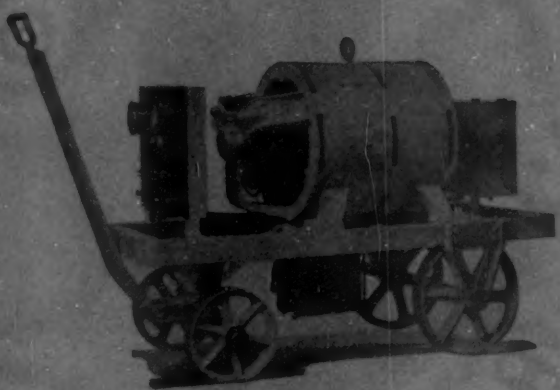

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